Information Technologies in Healthcare Industry **Volume 4**

Series Editor: Patricia Ordóñez de Pablos

Digital Healthcare in Asia and Gulf Region for Healthy Aging and More Inclusive Societies

Shaping Digital Future

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Shaping Digital Future

Volume 4

Volume Editor

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Series Editor

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Preface: Navigating digital health transformation in Asian and Gulf Region

Introduction

As COVID-19 emerged, the EU developed the EU4Health Programme 2021–2027—a vision for a healthier European Union—with a budget of €5.3 billion. Its general objectives are to improve and foster health and strengthen health systems (European Commission, 2023a). The 2018 Communication on Digital Health and Care (European Commission, 2023b) identified three main pillars for the digital transformation: "secure data access and sharing," "connecting and sharing health data for research, faster diagnosis and improved health," and "strengthening citizen empowerment and individual care through digital services." In rapidly aging societies, it is crucial to discover and use the potential of health data, transfer health knowledge and transform national health systems, empower citizens, and build stronger and more resilient societies (Almunawar et al., 2023; European Commission, 2023c).

According to WHO (2021), digital health is "the field of knowledge and practice associated with the development and use of digital technologies to improve health. Digital health expands the concept of eHealth to include digital consumers, with a wider range of smart devices and connected equipment" (p. 11).

Governments in Asia and Gulf region are working toward the digital transformations of their national healthcare systems (Challenges & Tasks Ahead of the Ministry of Health and Welfare of the Republic of Korea, Digital Economy Council of Brunei Darussalam, Qatar National Vision, Saudi Arabia's Vision 2030, Country Cooperation Strategy for WHO and Oman (2021–2025), Health Vision 2050 of Sultanate of Oman, Kuwait Vision 2035, and so on). The global outbreak caused by COVID-19 resulted in global disruption in societies, healthcare systems, and economies around the world. Researchers, clinicians, CEOs, and policymakers need to learn from experiences of public services and private companies and exploit the potential of advanced information technologies to build stronger national healthcare systems, better quality healthcare services and more inclusive and resilient societies. It is important to share country experiences and advance the digital transformation of national healthcare systems and infrastructures.

The book presents a collection of innovative research on digital healthcare, with four mains goals: (1) to cover two geographical regions (Asia and Gulf region) with important advances in digital healthcare; (2) to describe case studies in the field of IT and digital health; (3) to analyze latest advances in the field of digital healthcare; and

(4) to discuss implications for main stakeholders (patients, doctors, IT experts, directors, and policy managers) and recommendations for policymakers in these two regions and around the world.

The book has a high-quality collection of chapters addressing crucial topics in the field of digital healthcare, written by international experts in their fields of research and providing valuable insights and knowledge to transition to smart healthcare models and infrastructures in Asia and Gulf region. The chapters will provide frameworks, analysis, and empirical evidence, which can be useful to design and implement actions, policies, and strategies to build greener and more inclusive societies. It will promote meaningful dialogue and knowledge exchange among relevant stakeholders in the digital age.

The book is part of the Elsevier book series, *Information Technologies in Healthcare Industry*, which offers a valuable collection of books on actions, policies, and strategies for the digital transformation of the healthcare industry. It contributes to the understanding of the latest developments and challenges in the field of innovation and science in healthcare industry and helps to shape dialogue on the future of the digital healthcare for more inclusive and resilient societies. This Elsevier book series explores the deployment of digital solutions for person-centered integrated care in the future of the health industry, security issues in health data access, ethical and compliant use and sharing of health data, and the power of artificial intelligence (AI) to deal with disease outbreaks, among other themes. International leading experts from around the world participate in the books of this collection, sharing their valuable knowledge and insights in the field of digital health (Ordóñez de Pablos et al., 2022; Ordóñez de Pablos & Zhang, 2023).

As the Editor in Chief of this book series, I am extremely proud to present the third volume titled *Digital Healthcare in Asia and Gulf Region for Healthy Aging and More Inclusive Societies: Shaping Digital Future*.

About the book

The book presents a collection of 21 chapters structured in 5 main sections: Section I. Lessons from Covid-19 pandemic, healthcare services and preparedness for the future; Section II: Healthcare systems and healthcare workforce: Toward digital transformation; Section III: National healthcare visions and digital transformation of healthcare services and infrastructures in Asia; Section IV: National healthcare visions and digital transformation of healthcare services and infrastructures in Gulf region; and finally, Section V: Trends and implications for healthcare research agenda and policy.

Section I, *Lessons from Covid-19 pandemic, healthcare services and preparedness for the future*, has four chapters.

Chapter 1 states that "Indian pharmaceutical industry is the third largest in the world in terms of volume with a considerable growth and was expected to touch

USD 55 bn by 2020. In view of changes, prescribers are finding it difficult to keep themselves updated with the recent developments in medical science. In the era of information technology, the emergence and utilization of digital marketing has gained popularity among the marketers. Companies have started launching mobile app for patient awareness on various diseases and to ensure their adherence to treatment regime. A few organizations not only leveraged webinars, video chats, information portals, and platforms for prescribers, it has also equipped its field force with gadgets to disseminate real-time information on developments in therapy areas. Social media (SM) being a powerful medium of communication, it is only prudent that marketers use this tool effectively while designing marketing campaigns in order to create brand image of their products. There is a sizable amount of growth in pharmaceutical industry in terms of utilizing newer digital technologies for promotional strategies. The marketing experts in future will be required to have the skill of extracting useful information from all sources of information available digitally and use it to generate marketing content".

Chapter 2 affirms that "the Covid-19 pandemic has hindered the community's ability to carry out tasks such as procuring necessities. The use of technology to address necessities, such as purchasing food online, is extremely beneficial. Along with the relaxation of limits on people's freedom of movement, the availability of online meal delivery should be considered in the future. The purpose of this study is to discuss the effects of subjective norms, social isolation, food delivery hygiene, and food safety perception on the behavioral intention and behavioral continuance of online food delivery service users. Questionnaires distributed online were used to collect data. Only 399 of the 407 respondents who collected data could be used for further study. Data analysis was done with the Structural Equation Model-Partial Least Squares (SEM-PLS) statistical method and software WarpPLS 8.0. Behavioral intention was found to be influenced by behavioral continuance, subjective norms, social isolation, food delivery hygiene, and perception of food safety. The developed behavioral purpose is not the result of social isolation. Subjective standards also have a significant impact in determining Behavioral Intention".

Chapter 3 states that "health technology holds promise for early detection, and accurate diagnosis for timely access to mental health care. In this chapter, we review evidence on the use of health technology for early detection and diagnosis of mental illnesses. By leveraging information and communication technologies to provide better mental health care services in underserved areas, networked health systems and patients gain access to seamless, coordinated and continuing care. The advances in modern telecommunications, machine learning, AI, and health diagnostic equipment have the potential to deliver immediate and effective mental health care to the masses. This chapter presents a snapshot of various health technology applications; strengths and limitations of technology adoption and scale-up. Further research is needed to rigorously evaluate effectiveness, assess costs, and carefully consider potential risks of health technology".

Chapter 4 highlights that "healthy aging (HA) has been an active focus of research and practice ever since the World Health Organization conceptualized active and healthy aging. Measures to enable the elderly (those aged 50 years +) to live an active and good quality of life fall under the larger ambit of HA. As the engagement with digital information and communication technology expands, the elderly are found more interactive and involved with it as well. With the rise in the mental health burden, digital applications provide an extended opportunity to accelerate mental health awareness and intervention. Digital health or digital health applications can be multifarious ranging from Internet-based interventions, teleconsultations with healthcare providers, smartphone applications, interactive digital games, electronic records, and information systems. Thus the outcomes of these applications are manifold from increasing awareness to providing assistance, remote consultations, and digital interventions for mental health care and mental health promotion. The chapter purports to critically analyze the existing digital health applications available for mental health care and health promotion to enable HA. It also shares the perspective of the elderly as users while discussing the ethical concerns that surround digital mental health applications. HA should not just be a focus to reduce stigma, improve the mental health of the elderly, or enable them to contribute better, but fundamentally irrespective of age, everyone deserves to live a good quality of life. There is a need to better serve geriatric mental health services as we revolutionize with an edge in digital technology".

Section II, *Healthcare systems and healthcare workforce: Toward digital transformation*, includes four chapters.

Chapter 5 explores "the most important opportunities and threats facing the accounting information system (AIS) in hospitals when adopting the technology of the Internet of Things, and how the AIS can benefit from the opportunities offered by the use of the Internet of Things in hospitals and at the same time present proposals to address the risks of adopting the technology of the Internet of Things on the information system. The study found that the use of the Internet of Things will positively affect by providing multiple opportunities to develop the financial AIS and management of AISs and costs, including data entry as soon as the data occurs, data automation and analysis, improving the quality characteristics of the accounting information generated from the accounting system, providing data assist in evaluating performance using financial and nonfinancial indicators, assist in indexing patient records, provide accurate information on costs of health services, and assist in building new models that help simplify procedures, reduce service time, and facilitate audits and control procedures".

Chapter 6 states that "the integration of space internet technology with healthcare holds transformative potential, revolutionizing healthcare delivery, monitoring, and accessibility. In remote and underserved areas, space internet enables real-time telemedicine consultations, remote surgical support, and continuous health monitoring through wearable devices. It plays a pivotal role in monitoring and preventing infectious diseases, supporting rapid response to outbreaks. In space exploration, space internet ensures astronauts' well-being, offering real-time telemedicine, mental health support, and environmental health monitoring on extraterrestrial habitats. Blockchain technology enhances security and privacy in space health records. To address the digital divide, satellite-based Internet services promise universal access, promoting equity in healthcare delivery globally. Future developments in AI, bioprinting, diagnostics, and personalized medicine hold promise for superior healthcare on the Earth and in space. Despite challenges, the integration of space internet into digital health marks a revolutionary shift toward a more equitable, accessible, and personalized healthcare landscape".

Chapter 7 affirms that "sleep quality is an important factor for both physiological well-being and mental health, as adequate sleep encourages optimal brain function and enhances productivity. However, numerous individuals experience suboptimal quality of sleep, which can potentially contribute to the development of sleep disorders. One determinant of sleep can be established by utilizing a distinct aspect of the polysomnography (PSG) tool known as the electrocardiogram (ECG) signal, which can be converted into heart rate variability (HRV) data through processing. The aim of this research was to build a classification model with optimal accuracy in identifying human sleep cycles using HRV features based on ECG signals. This chapter uses the convolution neural network (CNN) as the proposed method, and then the features used are input into the CNN model as many as 18 features. Additionally, hyperparameter tuning is performed to attain the optimal results. CNN 95.15%, 88.37%, 86.03%, and 76.39% accuracy for 2, 3, 4, and 6 classes".

Chapter 8 observes that "the rise of AI in medicine is transforming healthcare by integrating data into clinical decision-making. This technology can improve cost, quality, and accessibility, but has limitations such as transparency and liability. Medical professionals must undergo training in this area and integrate AI into the curriculum across all subject areas. In the surgical field, surgeons can incorporate AI into their practices by collaborating with data scientists to gather data during patient care. Machine learning, natural language processing, artificial neural networks, and computer vision play a crucial role in learning about AI in surgery. Combining AI with surgical robotics could increase surgical expertise, patient outcomes, and medical treatment availability. AI has the potential to improve diagnosis, treatment, and outcomes in obstetrics and gynecology, but further research is needed to minimize bias and enhance adaptability. AI systems rely on comprehensive data access, but ethical concerns about patient information confidentiality need to be addressed".

Section III, *National healthcare visions and digital transformation of healthcare services and infrastructures in Asia*, has seven chapters.

Chapter 9 affirms that "post-COVID-19 pandemic, delivering telehealth services to elderly people has become a necessity across the world. However, countries such as Pakistan suffer from technological poverty and low digital literacy in aging populations. The aim of this chapter is to provide an understanding about the diverse challenges involved in (1) delivering telehealth services to elderly patients, as perceived by healthcare providers, and receiving telehealth services, as perceived by elderly patients; and (2) recommending solutions for telehealth sustainability for elderly patient care. Multiple challenges were indicated by both patients and providers, centering mainly around technological use and access, coordination and communication, delays in treatment and recovery, and the expense outweighing perceived benefits. We conclude that telehealth services for aging people in Pakistan, as well as in comparable countries and regions, must be partnered with state support for improving technological infrastructure and resources; digital literacy in aging populations; improved regulation of providers, developing national telehealth guidelines, and ensuring training and ethics; and maintaining a hybrid model in which the elderly are supported for regular physical check-ups and lab tests, along with multidisciplinary telehealth services".

Chapter 10 observes that "the rapid advancement of digital health technologies has catalyzed transformative changes in global healthcare systems. As member countries of the Association of Southeast Asian Nations (ASEAN) strive to harness the potential of digital health, there arises an increasing need to assess their progress, challenges, and opportunities. This research presents an exploratory analysis of digital health across ASEAN nations, utilizing the comprehensive framework provided by the Global Digital Health Monitor. The study employs key indicator categories, including leadership and governance, strategy and investment, legislation, policy and compliance, workforce, standards and interoperability, infrastructure, and services and applications, to evaluate the enabling environment for digital health. Drawing upon data derived from the Global Digital Health Monitor, this research systematically examines the digital health landscape, comparing scores and performances among ASEAN member countries. The findings illuminate strengths, achievements, and gaps within each nation's digital health ecosystem, offering insights into readiness and implementation status".

Chapter 11 states that "the development of the Internet and its related technologies such as SM platforms have become increasingly useful. A single definition of SM is difficult due to its evolving nature. Specifically, in the field of healthcare, SM is not only important for physicians and patients but also for pharmaceutical companies. SM marketing has become important to find out information about consumer behavior, market perceptions, better relationship with patients, and new market opportunities. Various SM platforms of top 25 Indian and top 25 MNC pharmaceutical companies were examined. It was found that most MNC pharmaceutical companies use SM platform aggressively with their own verified accounts. Compared to this, Indian pharmaceutical companies are not very active on SM platforms, with only a few companies being active. The use of various platforms such as Twitter, Facebook, YouTube, LinkedIn, and Instagram is limited by Indian pharmaceutical companies. Multinational pharmaceutical companies are high users of SM in order to reach out to the community compared to Indian pharmaceutical companies".

Chapter 12 proposes that "myopic retinopathy is regarded as a highly complex clinical condition within the field of ophthalmological study. Ongoing endeavors are being made to provide a precise definition, systematic classification, explanation of illness progression mechanisms, and creation of preventive and treatment measures. Emerging technologies, such as optical coherence tomography and AI, are progressively pivotal in understanding and managing myopic retinopathy. Additionally, teleophthalmology has arisen as a noteworthy breakthrough, offering remote diagnostic capabilities and addressing the healthcare disparity in underprivileged places. However, notwithstanding our acknowledgment of these technological advancements, there remain ongoing challenges pertaining to the protection of data privacy and the promotion of equitable technology access. While current treatments predominantly address refractive errors, novel digital technologies suggest alternative strategies that may offer potential avenues for reversing these conditions. The rise of telemedicine, enhanced by the evolution of AI and 5G technology, is revolutionizing the realm of ophthalmology. Despite existing challenges, this heralds a new era of comprehensive, sophisticated, and sustainable digital ophthalmic healthcare solutions".

Chapter 13 affirms that "technological progress is catalyzing a substantial healthcare transformation, shaping health behaviors through wearables and digital health technology. These advances amplify customer interaction, reduce costs, and aid decision-making, minimizing errors and streamlining supply chains. Despite COVID-19 constraining healthcare travel, digital healthcare has proven vital, enabling the industry to persevere. The relevance of healthcare provider—patient interaction endures through digital solutions, but privacy and cybersecurity concerns emphasize the need for integrated systems. Asia's healthcare travel sector swiftly evolves due to demand, technological advancements, and prolonged waits for Western public healthcare. Innovative healthcare solutions foster a patient-centric paradigm, highlighting adaptability in Asia's healthcare travel industry. Technology integration revolutionizes patient care, allowing physicians to engage with a larger population, enhance productivity, and deliver prompt treatments. Advanced diagnostics, analytics, and real-time monitoring customize interventions, reshaping interconnected healthcare services and presenting a new value proposition for Asia's healthcare facilities in the travel domain".

Chapter 14 states that "the digital health ecosystem is developing rapidly in tandem with the speed of information and communication technology. One of the advancements is the progress of AI, which enables healthcare devices with AI capabilities to assist in decision-making and execute those decisions without human intervention. This chapter assesses the potential of digital health, with a particular emphasis on the role of AI, in advancing digital inclusivity for the elderly group within the context of Asia in the post-COVID-19 era. The study aims to bridge the generational gap and actively engage older citizens in the ever-evolving healthcare landscape. Employing a qualitative methodology centered on secondary data analysis, this research conducts a thorough examination of the multifaceted implications of digital health, especially AI, in bolstering healthcare delivery that caters to the distinct requirements of older individuals. By delving into the synergies between AI and elderly healthcare within the Asian region, this study provides valuable insights into how technological innovations can not only elevate healthcare services but also address age-related challenges, ultimately nurturing a more inclusive and equitable healthcare system for the aging demographic. The overarching outcome of this research will contribute to the development of an AI assistant device for healthcare workflow that better serves the needs of elderly individuals in the Asian context".

Chapter 15 analyzes "the dynamic healthcare landscape in Asia, focusing on the impact of digital transformation and the integration of emerging technologies into the metaverse. We emphasize the transformative potential of AI, robotics, AR, VR, wearables, and blockchain in healthcare. The chapter provides an insightful metaverse overview, highlighting its revolutionary role in healthcare services. Sections dissect the contributions of these technologies to digital healthcare evolution, scrutinizing the metaverse concept and its healthcare implications. Challenges in integration, including ethical considerations, data security, and user experience, are meticulously identified and discussed. Innovative use cases receive special attention, showcasing technology's role in enhancing patient care, medical training, and healthcare delivery. The chapter also addresses unique challenges arising from the metaverse-healthcare convergence, such as privacy, accessibility, and the digital divide. It synthesizes key themes, emphasizing the metaverse's transformative potential in shaping healthcare across Asia. The chapter advocates addressing challenges for a technologically advanced, ethically sound, and patient-centric healthcare future in Asia, making a distinctive contribution to the field and stimulating further research".

Section IV, *National healthcare visions and digital transformation of healthcare services and infrastructures in Gulf Region*, has four chapters.

Chapter 16 studies "the role of big data in the development of healthcare in the Gulf Cooperation Council (GCC) countries. Big data in healthcare refers to the abundant health data collected from many sources, including electronic health records, medical imaging, payment records, and wearable devices. Thus it is a complex process of examining data and extracting information, including hidden patterns, that can help health organizations make more accurate clinical decisions. The study concluded that the use of big data in the health care sector in the Arab Gulf countries has led to an increase in the quality of health care, by providing better insights into patients at risk of disease, in addition to providing treatments and making more accurate clinical decisions. Moreover, big data analytics can be used as a transformational tool that helps provide many preventive and proactive treatment options. On the other hand, the study found that, despite the abundance of big data, it is complex and fragmented in nature, and there are many challenges associated with each step of processing big data, which can only be overcome by using advanced computing solutions".

Chapter 17 studies "how the proliferation of AI technologies in healthcare may impact, both positively and negatively, the delivery of patient-centered care in the Gulf region. The chapter begins with an overview of the increasing interest in the integration of AI tools into patient care delivery in the Gulf region as well as principal developments in this domain. Next, the chapter will analyze the potential benefits and harms of leveraging these technologies in healthcare through the lens of the patient—doctor relationship. On the positive side, AI can empower healthcare professionals by leveraging vast patient data into refining diagnostic accuracy and tailoring treatment plans. Furthermore, the potential advantages of AI in the areas of resource allocation and enhancing patient outcomes will be touched upon. On the potential harmful side, the chapter will discuss ethical considerations pertaining to AI integration, including data privacy as well as algorithmic bias and transparency. Throughout the chapter, the distinctive sociocultural and religious context of the Gulf region, where family involvement in healthcare decision-making and religious dictates hold significant importance, will be highlighted as apropos. The chapter emphasizes the need for a comprehensive ethical framework and implementation model that strikes a balance between harnessing the potential benefits of AI whilst safeguarding patient rights and enhancing the patient—doctor relationship. Such models must also account for the notion of whole person care and integrate patients' and families' values, beliefs, and preferences in their deployment".

Chapter 18 affirms that "medicines management is an integral element of Kuwait's national healthcare system, crucial for ensuring patient safety and the efficiency of healthcare services. However, challenges have arisen within Kuwait's medicine management system due to poor administrative linkages among related agencies. This chapter aims to propose a cohesive and efficient national medicine management system aligned with Kuwait's broader healthcare framework. The piece consolidates insights from various dimensions of the national medicine management mechanism, encompassing medicine registration, marketing procedures, retail pricing mechanisms, information gathering systems, and safety assurance mechanisms. By considering Kuwait's healthcare system and adopting a holistic approach, the chapter recommends four pivotal pathways and essential agencies to oversee national medicine management. These pathways encompass a comprehensive description of each agency's roles".

Chapter 19 proposes that "telehealth technology is a suitable solution to overcome inadequacy of healthcare services and resources. Despite the advantages of this technology, many products are still in the research and development phase, failed in the operational stage, or have not yet been introduced to the market. Since the real value of innovations is realized during the commercialization and profitability stage, the use of business models and frameworks can help investors to successfully commercialize telehealth products and services. In this chapter, the importance of using telehealth technology, reasons for the success and failure of this technology, and factors affecting its commercialization are explained. Discussing business models, their components, various approaches in applying business models, different types of business models, particularly for telehealth technology is another part of this chapter. Finally, a summary of the study conducted to create a telehealth business framework for Iran is presented".

Finally, Section V, *Trends and Implications for healthcare research agenda and policy*, includes two chapters.

Chapter 20 analyzes "the emerging trends in the healthcare industry using AI with a focus on the integration of deep learning and symbolic AI to address the limitations of traditional neural networks. It emphasizes the importance of knowledge-dependent deep learning and its relevance in cases where obtaining large volumes of data is challenging. The integration of deep neural networks with symbolic AI is highlighted as a means to enhance the understanding of raw data by discovering relationships and objects through knowledge infusion. This integration known as Neuro-Symbolic AI is noted for its ability to combine the strengths of both neural networks and symbolic reasoning, resulting in improved reasoning capabilities and explicability. The hybrid nature of Neuro-Symbolic AI is emphasized underlining its role as a unified framework for robust reasoning and interpretability. In this chapter, we explore rare diseases in the Gulf region and several non-communicable diseases prevalent in Asian countries, particularly those affecting the aging population. This discussion highlights how Neuro-Symbolic AI can effectively address these challenges".

Chapter 21 observes that "the healthcare research sector in the Middle East is substantially expanding, shifting from dependence on Western medical knowledge to pioneering research customized for its diverse population. Nations such as the UAE, Qatar, and Saudi Arabia invest substantially in this sector, aligning it with national agendas. These investments prioritize incorporating advanced technology such as AI and telemedicine, strongly emphasizing fostering innovation. The region has distinct obstacles due to its cultural heterogeneity and intricate health concerns. Notwithstanding these difficulties, there is a significant rise in the quantity of research produced and cooperation, both at a regional and global level".

Patricia Ordóñez de Pablos

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SECTION I

Lessons from Covid-19 pandemic, healthcare services, and preparedness for the future

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CHAPTER 1

Can digital and social media change access to healthcare information?

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Introduction

Indian pharmaceutical industry is the third largest in the world in terms of volume with a considerable growth from US$6 billion in 2005 to US$36.7 billion in 2016, and is expected to touch US$55 billion by 2020. The increase in the standard of living of an average Indian, higher consciousness and awareness for better health coupled with healthcare and medical policies have further added to the growth of the pharmaceutical industry (Ibef.org, 2017). In contrast, according to the Organization for Economic Co-operation and Development (OECD), India has only 0.7 prescribers per 1000 people. The disease burden due to lifestyle changes, ambition, work pressure among people and associated lifestyle diseases have made today's prescribers busy. The advances in the medical field are happening at a breakneck speed. In view of all these changes, prescribers are finding it difficult to keep themselves updated with the recent developments in medical science (OECD, 2017). With ever-increasing pressure on prescribers with information overload and thousands of brands available in the market, it is difficult for them to keep abreast with the latest changes happening in the pharmaceutical landscape. With physicians challenged for time due to increased patient in-flow, they have very little time to update their knowledge. The traditional model of a medical representative (Mr) meeting a doctor may no longer be effective. The efforts by Mr need to be complemented with the latest tools.

The Mr acts as a brand ambassador for the company and its brands or products. He/she is the one-point contact between the company and the doctors. The marketing department designs the marketing strategies to empower the field force/Mr with an objective to gain maximum market share for the existing products and to create demand for the new launches. The most important traditional marketing strategy that is considered to achieve maximum returns on the marketing investments made is Detailing. However, detailing fails to achieve the expected returns as it lacks proper engagement of all the stakeholders, also the cost involved doesn't justify the returns.

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A recent survey by Docplexus suggests that 80% of prescribers check product information online. 74% of prescribers want to communicate with Mr regarding new drugs, 68% want to limit the interaction to once a month and only 33% think that such interactions add value to their practice (Docplexus Insights, 2017). Hence, in the era of information technology, the emergence and utilization of digital marketing have gained popularity among marketers. Around 80% of internet users through smartphones and computers are seeking medical opinions online. Thus, the digital medium of marketing in the pharmaceutical industry can't be ignored. Digitalization has been at the core of marketing strategies across all industries contributing toward maximizing profits and increasing market share. It is said that the pharmaceutical industry has been slow in recognizing the potential of digitalization and is still embracing the traditional marketing strategies that revolve around the field force, specifically Mr (Bhagat, 2017). With changing times, pharmaceutical companies need to explore new avenues to effectively market their products, bridging the gap between prescribers' expectations and Mr offerings, making the interaction more desirable, impactful and interesting. This can be in some way achieved with newer digital technologies and social media (SM) marketing, which will create awareness among the prescribers for the product, giving way to more effective and informed communication. Mr should come across as an assistance provider for the prescriber rather than as a seller in making the right decision on the products or services (Bhagat, 2017). Digital marketing engages all stakeholders—Physicians, Salesforce, and Patients. New technology ranges from the use of newer tools of digital marketing for scientific detailing to prescribers to using SM for communication with prescribers and patients alike for providing better patient education, support and compliance. Pharmaceutical companies in India have already begun including this newer technology in their current marketing strategies, as new launches show. Companies have started launching mobile apps for patient awareness of various diseases and to ensure their adherence to treatment regimes. A few organizations not only leveraged webinars, video chats, information portals and platforms for prescribers, it have also equipped their field force with devices like iPads, which help disseminate real-time information on developments in therapy areas. Multinational companies see India as a ground for introducing tech innovations that can be replicated worldwide and they have introduced several tools like a heart and liver app and another one for vertigo exercises. Some of these are built on augmented and virtual reality to engage with both prescribers and patients (ETBrandEquity.com. 2017).

Some of the tools that empower digital media, but are not limited to, include

Website management

Websites assist in communicating with prospects and customers and are a convenient tool for establishing company and product identity. A website can make the business unique by demonstrating and showcasing content that is accessible and easy to understand by the target audience.

Apps

Through apps, companies can motivate patients to continue with a treatment regime and gain better control over the disease. Apps can assist Physicians in offering their services in a better way.

E-detailing

Pharmaceutical product detailing to doctors by MRs is believed to fetch the single largest return on marketing investments by the pharmaceutical companies globally, as of date. E-detailing is not a single entity but can take many different forms: from remote live discussion with a sales rep to a purely scripted interaction with a website or an Interactive Voice Response phone line. Most e-detailing models have been tried in the US and only some models, such as some forms of Scripted e-detailing have been shown by independent studies to increase prescribing compared to traditional detailing methods. Each e-detail model differs in its popularity and applicability to specific physicians, for example, GPs are more easily accessed than specialists in scripted e-details.

Augmented reality

These technological tools have started being used across the pharmaceutical industry globally and companies in India have started to use this technology as well mostly for marketing, product branding and providing patient education creatively.

Virtual reality

The use of virtual reality has become the newest buzzword in the marketing industry across retail, social and even healthcare. For those not familiar with the concept, virtual reality is used to tap into consumer behavior using challenging techniques to mold them into a desired behavioral pattern. Fairly recently, the pharmaceutical industry in India has begun to use this technology to strengthen relationships with its stakeholders, mainly with patients and healthcare professionals.

Sensor-based technology

There are strong indications of a digital healthcare revolution in the market, often referred to as wireless, digital, or mobile health. The basic idea is to wirelessly connect the patient with care providers to monitor their health and intervene as needed ideally preventatively as the patient goes about their normal life. The enabling technology to do so would rely on miniature, smart sensors incorporated as deployable, wearable, and implantable for the patient. Wearables are attractive because they require no medical procedure and travel with the patient.

Telehealth

As the world grappled with the challenges of the COVID-19 pandemic, the importance of telehealth was felt and experienced. Telehealth became a norm during restricted movements where the care seeker and provider connected online using digital platforms for healthcare-related consultations.

Digital and social media

With the intensification of interactive communications, digital technologies and SM, various challenges have appeared for the practice and theory of advertising and marketing in the Indian pharmaceutical industry. According to a study by Kozinets et al. (2010), newer digital technologies, including SM, is increasingly developed by companies to advertise content and newer forms of communication practices emerge as the market space changes (Kozinets et al., 2010). A study by Rokka et al. (2013) identified that in addition to the use of SM to create brand value and the challenges associated with it, companies can leverage the strengths of their employees to create a positive image of the company and the products (Tienari, 2014). A paper by Schultz and Peltier (2013) presents subjective evidence regarding the continuous efforts that are required for consumer brand engagement involving SM and the challenges associated with it. The authors recommend that the advanced tools of communication be used to create long-term impact regarding brands rather than focusing on short-term revenues (Schultz & Peltier, 2013). A study by Voorveld and van Noort (2014) examining cross-media campaigns found that forward encoding and multiple source perception contributes to campaign results (Voorveld & van Noort, 2014). SM being a powerful medium of communication, it is only prudent that marketers use this tool effectively while designing marketing campaigns to create a brand image for their products. There is a sizable amount of growth in the pharmaceutical industry in terms of utilizing newer digital technologies to their existing promotional strategies.

A study by Alkhateeb and Doucette (2009) contends that physicians are willing to adopt newer techniques of promotion such as electronic detailing (e-detailing). Factors leading to the adoption of new technology by physicians include relative advantage, peer influence, attitude, speciality, and restrictive access (Alkhateeb & Doucette, 2009). As physicians are interested to learn, pharmaceutical companies should mold themselves to cater to the changing needs of physicians to make newer information easily accessible.

A study by the Anderson and Jiang (2018) in the US noted that online health information is sought by one in three American adults and the internet has become a diagnostic tool. A total of 41% of respondents online diagnosis was confirmed by their medical professional; women are more likely than men to find a possible diagnosis;

half of the enquiries online are made for someone else; 26% read about the medical condition of someone else and young adults with college education are more likely to seek online health information (Fox & Duggan, 2013). The use of the internet to seek health information is corroborated in an earlier study which found that young adults are more likely to seek online health information (Bhaskaran et al., 2017). In view of changing dynamics where both health providers and seekers are turning to digital media platforms, pharmaceutical companies have to look toward developing and forming unique forms of digital platforms and create content easily accessible to both groups depending on the importance of information to be provided.

An increase in access to healthcare, better infrastructure and the increasing efforts by the pharma industry to penetrate and access markets can be supplemented by the optimal use of digital media and various platforms. The pharma companies have to explore developing and forming unique means of connecting with the target market using advanced mechanisms like sales force engagement, consolidation of field force, strengthening marketing channels with the adoption of digital marketing, and organize patient education programs.

Despite the willingness of health providers and seekers, major pharmaceutical companies in India—both domestic and multinational—lack intent in leveraging the expanding digital health space (Business Standard, 2018). The digital health of the Indian pharma industry was published in a report titled "Indian Pharma Digital Health Report 2015." The report had a significant observation that the major pharmaceutical companies do maintain a presence on SM platforms yet their level of active engagement with consumers remains quite low. A few probable reasons for pharmaceutical companies not aggressively adopting digital platforms for marketing communication include ambiguous regulations, orthodox marketing outlook, and difficulty in aligning online and offline marketing activities to name a few (Docplexus, 2018).

Competencies of digital marketing

Ventola has argued that SM tools could enhance healthcare professionals learning and networking experience but could also pose risk with data privacy issues and professional risks (Crush, 2011; Antheunis et al., 2013; Ventola, 2014). It is important for marketers to adhere to core principles of marketing while adopting new digital tools. The pharmaceutical industry is no different. One of the ways to connect is through digital media, including SM. Further, patients and professionals expect flexibility of time in using SM (Antheunis et al., 2013). According to Grajales et al. (2014), the development of web 2.0 technologies resulted in enhanced accessibility and communication of information by patients and healthcare organizations respectively. Individuals and businesses have the opportunity to promote their blogs, reviews, opinions, services and products, which in turn generates immense information (Grajales et al., 2014).

This implies that marketing experts in future will be required to have the skill of extracting useful information from all sources of information available digitally and use it to generate marketing content. Micu et al. (2011) believe that companies that adapt to new technologies are normally in a position to take first-mover advantage. Further, digital and technology-based applications could be used to enable better marketing research (Micu et al., 2011). The plethora of various SM platforms today provides ample opportunities for marketers, especially pharmaceutical marketers, to dig data, understand healthcare providers and patient requirements, study enabling factors and barriers in providing and accessing healthcare and customize their marketing communication for better acceptance and impact (Micu et al., 2011). Mulhern echoes the fact that marketing communication changes with digitalization. Digital media also brings in changes from marketing communication practices to understanding consumers. The improved framework for communicating in the digital world includes integrated marketing communications, decisions based on data, cross-media integration and communication with multiple stakeholders (Mulhern, 2009). According to Budden et al. (2011), marketers' focus on college students to channelize the best methods of marketing communication is based on students' internet usage information (Budden et al., 2011). Guraya (2016) studied medical students' usage of social networking sites (SNSs) for educational purposes. The study found that the majority of medical students use SNSs, of which a few use to share academic and educational information through these SNS (Guraya, 2016). For pharmaceutical companies, engaging medical students through SM would be an investment opportunity.

India is a country that is witnessing rapid growth in the number of individuals adopting the internet and using it to enhance their lives. The urban centers in India have seen an increase in the use of digital media. Rural areas are not too far from adopting digital media compared to their counterparts in urban areas. It was reported that from 190 million internet users in 2014 it is going to increase to 550 million in 2018. The reports stated that more than urban areas, the rural areas will witness tremendous growth in internet user base. It is expected that the internet user base in rural areas will increase by 40% every year from 60 million in 2014 to 280 million in 2018 (Business Today, 2018). The changing landscape of internet use is also witnessed in the Indian pharmaceutical industry. The top 20 pharmaceutical companies are moving away from old ways of marketing and are using digital content for the same. The pharmaceutical industry's spending on digital communication is expected to increase by 50%, according to the reports. Digital communication is primarily expected to happen via SM and mobile apps (Raghavan, 2016)· According to a survey conducted by BCG's Center for Consumer and Customer Insight, more than 50% of the individuals who have access to the internet have a tendency to use the internet to make an informed decision before making a purchase. Thus, consumers are quickly getting used to taking advantage of the benefits that internet-based technology can give (Bajpai et al., 2017). Pharmaceutical companies can directly interact with consumers on SM and garner attention toward some of their new products and the benefits of it.

Digital marketing and brand health

According to Bayo-Moriones and Lera-López (2007), if the perspective of the consumer is taken into consideration, the use of information communication technologies offers numerous benefits such as product diversity, cost reduction, competitive pricing, wide product selection, richer and participative information, convenience and efficiency. These benefits are further enhanced by online social networking as proactive communication by consumers is possible (Bayo-Moriones and Lera-López, 2007). An example of online social networking would be various individuals and groups sharing information about their health using SM platforms with the objective help people in the community benefit. For instance, individuals can use online social networking to seek out others opinions regarding particular products

Tyrawski and DeAndrea carried out a content analysis of pharmaceutical companies and their drugs on SM. The study aimed at understanding pharmaceutical companies' ways to engage with the general public and market their drugs. The study focused on Direct to Consumer Advertising (DTCA). It was found that pharmaceutical companies provided information useful for patients, who interacted with these companies through comments. The communication also contained drug product claims with the majority of claims stating only benefits compared to risks. It was found that companies adhere to the FDA's definition of help-seeking DTCA (Tyrawski & De Andrea, 2015). A Nielsen survey found significant differences among people in various countries and cultures regarding trusting sources of advertising (Marketing Charts, 2018). Young adults in the age group of 18–24 years are more inclined to use SM for discussion on health-related issues, trust health information shared by others on SM, have at-least one app related to weight, exercise or diet and even doctors have faith in improved quality of care given to the patients in the US (Getreferralmd.com, 2018). In India healthcare professionals are a little behind in using SM, which probably could be attributed to the fact that they have limited understanding regarding the scope and benefits of SM (Creation.co, 2018).

Chugh and Gajare (2023) found that physicians are much more receptive to digital marketing and communication, especially after COVID-19 (Chug & Gajare, 2023). A study by Tabiat (2022) found that to create brand loyalty among consumers, companies shall provide the most up-to-date, new and relevant information thereby creating a motivating factor for establishing brand loyalty (Tabiat, 2022). The author asserts that in case of Lebanese pharmaceutical companies, SM marketing improved brand visibility, use of social communities and social publishing. Alarsali and Aghaei (2022) opine that during the stage of a new product launch, digital marketing tools can be leveraged by companies. Digital marketing campaigns during such stages can help pharmaceutical companies disseminate information to a large group of target customers, that is, doctors (Alarsali & Aghaei, 2022).

Stories are a powerful medium to convey messages. Pharmaceutical companies can use SM to create stories that effectively communicate messages regarding brand(s). It may lead to creating a positive image in the minds of the target customer, that is, doctor. Brand stories with images, specifically, human pictures are positively linked to higher engagement by users. Hence, companies shall identify these possibilities and strive to create a two-way communication thereby understanding consumers/customers better to improve products and offerings.

Conclusion

A mixture of different factors has led to an ever reducing return on investment from traditional marketing practices. This eventually led pharmaceutical companies to use digital and SM marketing compared to traditional one-on-one marketing. Product management and leadership teams now understand the need to have a digital strategy in place as a part of their larger marketing strategy. Currently, attempts are being made in this direction by technology companies engaged in the development and implementation of different mobile applications, sensors-based technologies, SM platforms, and novel technologies that might include augmented and virtual reality.

The young population accesses information using social and digital media, including healthcare. Various SM platforms and tools have been added over the years that allow access to information in almost real-time. With an added emphasis on digital health and wearables as devices that have become common in the lexicon regarding digital and SM, more people in future are expected to access healthcare information online. Further, regulations regarding these digital platforms are emerging across the world where the balance between healthcare information provided and data privacy needs to be struck. With the evolving landscape of digital and SM platforms, the access to healthcare information is poised to transform.

Authorship statement

CBZ, AG and MDJ equally contributed to the conceptualization of work, writing and reviewing manuscript. RR reviewed and revised the manuscript.

Conflict of interest

Authors declare no conflict of interest.

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CHAPTER 2

Food safety and online food delivery apps post-COVID-19 in Greater Jakarta—Indonesia

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Introduction

The significance of sophisticated information technology (IT) within the healthcare sector is of utmost importance and should not be underestimated. The technology possesses the capacity to generate substantial beneficial effects in various crucial domains, finally resulting in enhanced provision of healthcare to patients, heightened operational effectiveness, and superior results. The field of IT has a substantial impact on the domains of food safety and healthcare, facilitating advancements in operational procedures, safety protocols, and overall outcomes within these vital industries (Maiberger & Sunmola, 2022; Sharma et al., 2023). One of the simple solutions regarding food and healthcare is the online food delivery (OFD) application. People can buy food, place orders, and make payments to several restaurants using a single application if there is an OFD app available (Ancín et al., 2022; Khayer & Bao, 2019). This is a clever and effective solution that makes the presence of an OFD app a smart and efficient option (Foroughi et al., 2023; Mantravadi & Srai, 2023). The application for OFD is a mobile app-based application that brings together food merchants and food consumers (Candra et al., 2021; Poon & Tung, 2022). All aspects of the transaction, including selection, ordering, and payment, take place online. Using the most recent technologies, OFD services intend to make the process of ordering food and beverages more straightforward and expeditious (Rao et al., 2022; Sgroi, 2022). Customers merely need to place their orders for food and beverages using their smartphones, and then the delivery officer (driver) will bring the order to the specified location. It is useful for owners of culinary businesses since it allows them to reach more and more clients without requiring them to put in any additional effort. Online meal delivery is one example of this. In addition, there are numerous food and drink options available to choose from when using the OFD program. These options come from a variety of restaurants. This is beneficial to customers. In addition, the benefits

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of the delivery application are also realized. These benefits include the capacity to locate information about food that can be delivered to the desired location, as well as the ease of ordering and paying for food after the program has been loaded on a smartphone (Chakraborty et al., 2021; Daud & Min Yoong, 2019; Lau & ng, 2019). In addition, this information can be found via the application.

The widespread spread of the COVID-19 epidemic across the country has resulted in changes to consumer shopping patterns that are technologically advantageous (Alkhunaizan & Ali, 2022; Cruz-Cárdenas et al., 2021; Fajrian, 2020). One shift that was highly visible during the epidemic and continues to be so to this day is the increased use of online meal delivery apps for the purpose of placing food orders (Ng et al., 2022; Troise et al., 2020). The amount of money provided by OFD services was 78.4 trillion IDR (DataIndonesia.id, 2022). There has been a lot of success with the expansion of OFD because of how quick and convenient it is. In addition, the growth of technology and the rise in the number of people using the Internet in Indonesia will contribute to the expansion of this service. By the year 2022, the population of Indonesia will have increased to 204.7 million people, with many people having access to the internet in the country's largest cities (Badan Pusat Statistik, 2022; wearesocial.com, 2022). This is borne out by the findings of a survey that was carried out by MarkPlus during the pandemic period, which found that 44% of respondents in the UK shop for products online. In addition, purchasing online was the method of choice for 84% of respondents when the pandemic was going on. Many of the items purchased are consumable foods and beverages.

As the COVID-19 epidemic continues to spread around the world in March 2020, more and more people are turning to the convenience of ordering meals online and having them delivered to their door. Consumers are more likely to purchase their meals through OFD rather than going to a food provider like a restaurant or dining store during this COVID-19 epidemic to reduce the risk of transmission of the virus. It is becoming increasingly common during pandemics for people to order meals online and have them delivered to their homes. DataIndonesia.id (2022) found that 64% of users in Indonesia reported using OFD services more frequently during epidemic times. This rise might be attributable to issues about the hygiene of food delivery or people's perceptions of the safety of food (Cha & Borchgrevink, 2019; Mohaydin et al., 2017; Tran, 2021). In addition, social isolation can be an issue because of restrictions or quarantine times, which might be a negative influence (Raza et al., 2021; Scheinfeld & Voorhees, 2022). GrabFood and GoFood are the two companies that offer their respective messaging services in the Indonesian market. Many people who order food online have at least one of these applications on their phones. According to research published by Industry OFD in 2021, GoFood will become a popular app service that will be hard for consumers to forget.

The availability of numerous applications for the delivery of meals ordered online in Indonesia today has resulted in a rivalry that looks to have won the favor of customers (Digital, 2022; grandviewresearch.com, 2019). Not only to entice customers into using the OFD application, but also to figure out how to persuade customers that they should be able to use the online food delivery application continually and, in the future, which is something that may be referred to as behavioral continuity. In response to this, the online food delivery app provides a service that is quick, secure, and convenient; it also offers a wide variety of selections; it runs extensive promotions; and it continues to enhance its services both in terms of its application and directly. This is desired so that customers get the impression that the application not only offers them convenience but also justifies their continued use. Subjective norms, social isolation, food delivery hygiene, and the perception of food safety are all examples of factors that might impact a buyer's decision regarding whether to utilize an online meal delivery program on a continual basis.

Literature review

The impact of cutting-edge information technologies on individuals, organizations, governments, and the global economy is far-reaching and pervasive (Basile et al., 2023; Vishwakarma et al., 2022). The internet and mobile devices, among other information technologies, have fundamentally altered the way people interact with one another. They make it possible for people all over the world to instantly communicate with one another, which boosts teamwork, knowledge exchange, and spontaneous connections. This is crucial in both private and professional interactions.

By eliminating the need for human intervention, time, and resources, information technologies help streamline and improve efficiency. By streamlining their processes, businesses can boost production and speed up the delivery of their goods and services (Maiberger & Sunmola, 2022; Pietronudo et al., 2022). Access to large amounts of knowledge has improved dramatically with the advent of the internet and digital libraries. This spread of information allows people to educate themselves, make better choices, and keep up with the latest developments in a variety of fields. By bridging geographical and political boundaries, cutting-edge information technologies contribute to globalization (Rao et al., 2022; Vishwakarma et al., 2022). This creates fresh possibilities for business, cooperation, and mutual enrichment.

Innovation is fueled by the availability of IT, which facilitate study, creation, and application of novel concepts. New discoveries in fields like artificial intelligence (AI), machine learning (ML), and biotech can only be made with the help of cutting-edge information technologies (Pant et al., 2022; Pietronudo et al., 2022; Topal & Mercan, 2023). With the advent of electronic health records (EHRs), telehealth, wearable tech, and cutting-edge diagnostics, healthcare delivery has been revolutionized (Basile et al., 2023; Paul et al., 2023). They boost patient care, lessen the likelihood of medical mistakes, and broaden people's access to medical treatment.

It is impossible to monitor the spread of disease, coordinate healthcare resources, and notify the public during a public health emergency without digital tools (Chakraborty et al., 2021; Pant et al., 2022). This was most noticeable during the widespread spread of the COVID-19 virus. Patient care, efficiency, accessibility, and research are just some of the many areas that have benefited greatly from the widespread adoption of digital technologies in the healthcare sector (Egarhos, 2023; Raimo et al., 2023). Healthcare companies need to change to take advantage of technological advances while also meeting the difficulties of data privacy, system interoperability, and technology ethics (Ancín et al., 2022; Sontakke et al., 2023). This study will highlight the use of IT and its impact on healthcare, especially in OFD post-COVID-19. The big issues in this study will be food safety and technology will support the healthcare (Dal Mas et al., 2023; Grau-Noguer et al., 2023). Theory of Planned Behavior (TPB) will be the main focus to be used in this research.

An extension of the Theory of Reasoned Action is the TPB (Ajzen, 2020). The TPB explains that people's actions can be shaped by external factors since they are always guided by some sort of purpose. The TPB model postulates that most human behavior may be explained by a combination of intrinsic motivation (the desire to do something) and free will (the ability to choose whether to do something) (Al Amin et al., 2021). Attitude toward the activity, the subjective norm regarding the behavior, and the perception of one's own ability to control one's behavior are the three components that determine the desire to engage in the behavior.

Subjective norms are defined as an individual's belief about whether to engage in a behavior in accordance with the opinion of his or her neighbor, according to the Ajzen framework proposed in the study (Altin Gumussoy et al., 2018). To a greater or lesser extent, people's actions are impacted by those of their social circle, including friends, family, and acquaintances.

Subjective norms, as defined by Mafabi et al. (2017), are the expectations that an individual places on those closest to him. One's sense of social pressure to act in a certain way plays a role in shaping this kind of expectation. An individual's behavior is influenced by their internal and external drives to conform to authority.

Individuals' attitudes and actions are influenced by subjective standards to the extent that they conform, consciously or unconsciously, to those of the group or majority to which they belong. Social pressure is a major factor in shaping people's behaviors and decisions. The effect of societal norms can lead people to act in ways that are counter to what they would have done if they were free to act whenever they pleased (He et al., 2020).

According to Raza et al. (2021), people are socially isolated when they do not have close relationships with other people. Social isolation is defined as the state in which humans maintain a complete lack of contact owing to catastrophes occurring everywhere, or the objective physical separation from individuals, and other people, or living geographically and temporarily alone (Al Amin et al., 2021). The emergency status also applies to the COVID-19 pandemic. To slow the spread of the coronavirus during the current COVID-19 pandemic, people should restrict their contact with others, keep their distance, and participate in fewer group activities. Therefore, social separation modifies regular living and individual consumption patterns (Abu-Taieh et al., 2022).

The desire or interest to conduct secondary behavior, which signifies a person's willingness to behave, is referred to as behavioral intention. In behavioral science, intent or want is the driving force underlying the existence of the activity itself. In this study, behavioral intention demonstrates a person's proclivity to employ specific tactics to help them reach their goals. A person's level of technology use can be predicted by their desire to continue using and influence other users. According to Yu et al. (2022), behavioral intention is defined as the conduct after utilizing something that there is an intention to reuse and maybe recommend to others.

Tran (2021) defines behavioral continuity as the customer's intention to continue or discontinue using the system based on earlier decisions. The amount to which the perceived performance or experience is or is not in accordance with the initial expectations influences consumer intent or use. Continuing use of OFD during pandemics may continue if the individual believes that ordering food online safely during the COVID-19 pandemic (Al Amin et al., 2021).

Food safety is critical because it attracts consumers' attention. This covers the safety of packaging, production techniques, and the hygiene of the food itself (Al Amin et al., 2021; Cha & Borchgrevink, 2019). According to Tran (2021), food safety concern is a picture of consumer concerns about the quality of food packaging, food materials, and environmental toxins that can harm them physically because consumers are paying more attention to food safety with an emphasis on its manufacturing process, quality of processing, and additional food processing. As a result, consumer awareness of food safety is growing.

As the COVID-19 pandemic continues, changes in customer behavior force OFDs to focus on the health and hygiene of the food services they provide (Tran, 2021). Food delivery hygiene is related to the ability of food delivery to keep food delivery services safe and clean (Al Amin et al., 2021). Cha and Borchgrevink (2019) conducted research that showed the issue is not only about kitchen hygiene but also about its distribution. To handle problems in the kitchen, restaurants must ensure the quality of the food served as well as proper hygiene and sanitation; for shipment, this problem is addressed by ensuring that the carrier is in good health and condition. Because of the aforementioned factors, consumers are more interested in utilizing OFD.

According to Ajzen's TPB (2020), subjective norms have a favorable influence on behavioral intentions for specific actions. This is the case for a number of different behaviors. According to the findings of a study (Sia & Jose, 2019) carried out on homeowners in Kerala, India, concerning their behavioral intention to construct ecologically friendly homes. The findings of empirical research indicate that there is a substantial relationship between a person's subjective norms and their intentions towards their actions. Later, research on the perspective of games that have an effect on social and political concerns was carried out (Peña et al., 2018). This research took into account the belief in social dominance held by students in the United States. The findings of this research indicate that there is also a connection between subjective norms and the intention to behave in a certain way.

Research on the function of behavioral intention as a mediator in the interaction between attitude, subjective norms, perceived behavioral control, and knowledge-sharing behavior was carried out (Mafabi et al., 2017). A link between the effect of full mediation of behavioral intention and subjective norms was also found, according to research that was carried out in Uganda on medical professionals working in two different hospitals. This conclusion is supported by studies conducted by Altin Gumussoy et al. (2018) and Cheng et al. (2021), both of which say that there is a connection between behavioral intention and subjective norms and that this connection is significant. After reviewing the aforementioned research, one can reach the following conclusion: the existence of behavioral purpose is not immune to the influence of individual perception itself, often known as so-called subjective norms. Thus, this research can establish hypotheses that will be tested:

H1: There is a relationship between subjective norms and behavioral intention.

The prevalence of the COVID-19 outbreak drove the government to adopt rules that require the people of Indonesia to remain inside their homes and restrict activities that take place outside for a period of time. This practice, which can also be referred to as social isolation, was put into place. As a direct consequence of this social isolation itself, day-to-day activities and routines in society undergo transformation. Isolated societies are more conscientious about the kind of foods they consume on a regular basis and the quantities of food they consume (Tran, 2021). Because of this, the growth of social isolation has resulted in an increase in the usage of OFD. This is due to the fact that OFD offers efficient delivery services, which facilitate the formation of social interactions in situations when physical isolation is present. According to the findings of a study that was carried out by Scheinfeld and Voorhees (2022), it was found that the usage of social media grew during the period of the social isolation pandemic COVID-19. This indicates that there is a link between social isolation and behavioral intention.

Zacharis and Nikolopoulou (2022) carried out research with the purpose of determining the characteristics that indicate the behavioral intention of students to use eLearning learning platforms during or after the COVID-19 epidemic. The findings indicate that the occurrence of social isolation has an effect on students' intentions regarding their behavior. This is also reinforced by research carried out by Almazroa and Gulliver (2018), whose primary objective is to investigate the elements that influence travel behavior in settings that have become more typical. It may be claimed that there is an intervariable influence, as the results demonstrated that the behavioral intents of travelers in new normal situations occurred as a result of the existence of earlier social isolation. Thus, this research can establish hypotheses that will be tested:

H2: There is a relationship between social isolation and behavioral intention.

The purchase behavior of consumers with regard to OFD services revealed that consumer behavioral intentions had an effect on food delivery service (Chotigo & Kadono, 2021; Ng et al., 2022; Roh & Park, 2019). According to the findings of some recent research (Al Amin et al., 2021), there are a number of elements that influence the behavior and intentions of consumers regarding the use of mobile food delivery. The findings indicated a connection between the food delivery method and the intended behavior. The research that was carried out by Ko and Ni (2020) looked at food delivery in relation to a number of important factors, one of which was behavioral intention. The results of an analysis using structural modeling equations showed that the manner in which food is delivered has an effect on people's intentions towards their conduct. Cha and Borchgrevink (2019) investigated the relative effect of consumer behavioral intentions on the services that food delivery companies provide by using samples collected from patrons of restaurants. The findings of structural equation modeling indicate that connections can be made between the two. Thus, this research can establish hypotheses that will be tested:

H3: There is a relationship between food delivery hygiene and behavioral intention.

This research was carried out by Liu and Lee (2018) with the intention of gaining knowledge of how customers feel about the level of food safety at restaurants. The findings indicate that the state of food safety in restaurants has an effect on the consumer's intentions towards their behavior. Isoni Auad et al. (2019) carried out research on customers of food trucks in Brazil to have a better understanding of how people there feel about the significance of food safety. Customers indicate that their decision to buy meals from a food truck is influenced by how safe the food is. A similar research was conducted by Li et al. (2018), who looked into how the food safety issue affected the purchase decisions of consumers. As a result of the food safety crisis, consumer purchase intentions have dropped precipitously, which demonstrates the influence that food safety has on both behavioral intentions and food safety itself. Ray and Merle (2018) carried out research that showed that customers pay great attention to the safety of the food, which is the determining factor in whether or not they buy meals in a restaurant. Thus, this research can establish hypotheses that will be tested:

H4: There is a relationship between the perception of food safety and behavioral intention.

The connection between a person's behavioral goals and their level of behavioral consistency Research carried out by Aydınlıyurt et al. (2021), demonstrated that maintaining a consistent pattern of behavior provided a competitive advantage when pitted against the use of gamified applications. An enhanced expectation-confirmation model framework was designed and tested (Mamun et al., 2020) to explore IT continuance behavioral for workplace and personal use. The findings indicated that there was a connection between the behavioral intentions and the continuance behavioral that was seen. Kuo et al. (2018) conducted research to determine the factors that could influence the degree to which hospital staff members adhered to the EMR privacy policy. According to the findings of the data collected from health professionals, there is a connection between behavioral intention and continuance behavioral. To investigate the consistency of Alipay's user pattern by putting forward an integrated conceptual framework (Khayer & Bao, 2019). The study emphasizes how the capability to deliver context-based information to users plays a crucial role in influencing the continuance of mobile payment behavior such as Alipay. Specifically, the study focuses on how users' intentions to use Alipay continue to evolve over time. According to the data that was gathered from people who used Alipay in China, it was found that the continuity of behavior is determined by the benefits that the user himself perceives to be associated with using the service. Yu et al. (2022) carried out research on the usage of rich communication services in students, and the results showed that behavioral intention has an influence on continuance behavioral. Thus, this research can establish hypotheses that will be tested:

H5: There is a relationship between behavioral intention and continuance behavioral.

According to the findings of some recent research (Al Amin et al., 2021), there are a number of elements that influence the behavior and intentions of consumers regarding the use of mobile food delivery. The statistics from the users of the mobile meal delivery service suggest that there is a connection between the perception of food safety and the continuation of behaviors. Ko and Ni (2020) carried out this research to investigate the food safety-related skills possessed by workers in the food service industry. The results of the study of structural equations demonstrate that the quality of food has an effect on the continuity of behavioral patterns. This research was carried out by Liu and Lee (2018) with the intention of gaining knowledge of how consumers feel about the safety of food. The findings indicate that customers place a significant emphasis on the safety of their food while making repeat purchases. Therefore, the quality of food has an impact on the consistency of behavior. Thus, this research can establish hypotheses that will be tested:

H6: There is a relationship between the perception of food safety and continuance behavioral.

Young consumer groups have become increasingly receptive to the practice of placing food orders over the Internet ever since the O_2O model came into existence. However, following the initial ingestion, some consumers only use it sometimes or never again. Because of this, the question of how the platform might best encourage consumers to make subsequent purchases has become an essential one. According to the findings of a study that was carried out by Pang and Shao (2021), the continuity of behavior is influenced by the convenience, presence, and benefits offered by food delivery services. Ng et al. (2022) carried out this study with the intention of discovering and studying the influence that the COVID-19 epidemic has on customer satisfaction with McDonald's meal delivery services. The findings demonstrated, through the participation of McDonald's customers, that sanitary meal delivery services that enhance customer satisfaction have an influence on continued behavior. Thus, this research can establish hypotheses that will be tested:

H7: There is a relationship between food delivery hygiene and continuance behavioral.

Because social isolation and behavioral continuity have been shown to be related (Wang et al., 2022), the purpose of this study is to discover and empirically test the important elements that predict consumer behavior with regard to mobile food ordering apps. Data collected from users in China demonstrates that social isolation has a direct and immediate impact on the behavior of continuance. In their study on the topic (Raza et al., 2021), the researchers looked into the relationship between social isolation and acceptance of the learning management system in the context of the pandemic condition of COVID-19. According to the findings, there is a connection between being socially isolated and a lack of behavioral continuity. The purpose of the study that was carried out by Al Amin et al. (2021) was to determine the aspects of consumer behavior and intentions regarding the utilization of OFD services. According to the findings, a correlation may be drawn between social isolation and behavioral consistency. Thus, this research can establish hypotheses that will be tested:

H8: There is a relationship between social isolation and continuance behavioral.

One of the sports service applications that focuses on bookings for sporting events is called the X app. To remain competitive in the face of growing trends and targeted markets, X apps need to enhance and raise the number of their existing customers who stick with them. Accordingly, the findings of the study that was conducted by Syafinal and Suzianti (2020) provide an effective technique for increasing customer loyalty and retention. The findings indicate that behavioral consistency might be affected by subjective norms. This study, which was carried out by He et al. (2020), intends to investigate the elements that determine the degree to which customers feel connected to platforms for environmental preservation and community welfare. The findings indicate that individual norms have an effect on the continuation of behavior. Liu et al. (2019) developed this paper with the purpose of investigating whether and how social media behavioral continuity variables work differently across social networking sites and microblogging. These objectives are based on the TPB and the self-regulation framework. Both of these theories are foundational to the study. The results of his research indicate that there is a connection between individual norms and the consistency of one's behaviors. Liang and Shiau, (2018) seek to study the implications of privacy and subjective norms on the relationship between customer happiness and AET repurchase intention. Specifically, the authors want to look at how these factors influence the relationship. According to the data collected from customers, there appears to be a connection between behavioral continuity and subjective standards. Thus, this research can establish hypotheses that will be tested:

H9: There is a relationship between subjective norms and continuance behavioral.

Based on the above explanation, starting from a background of study and literature review then continue with hypothesis development. Then the research model in this study as seen in Fig. 2.1.

Research method

The methodology of this study is based on quantitative approaches. If a strategy known as descriptive associative analysis is used, the research results should be able to respond to the overall hypothesis. The data collection method that will be used will be questionnaires that will be made available online and written in Indonesian. Questionnaire were distributed during the post outbreak of COVID-19 in the middle of 2022. Measurement indicators for each variables will be adapted from previous studies: food delivery hygiene (Tran, 2021); subjective norms (Al Amin et al., 2021; Li et al., 2018; Liang & Shiau, 2018; Ruby et al., 2019; Sia & Jose, 2019; Tran, 2021); behavioral intention (Abu-Taieh et al., 2022; Duong et al., 2022; Ko & Ni, 2020; Raza et al., 2021; Sia & Jose, 2019; Yu et al., 2022); social isolation (Al Amin et al., 2021; Raza et al., 2021; Tran, 2021); continuance behavioral (Liu et al., 2019; Tran, 2021); perception of food safety (Al Amin et al., 2021; Tran, 2021). Purposive sampling was used as a sampling method, and the criteria for participants included a

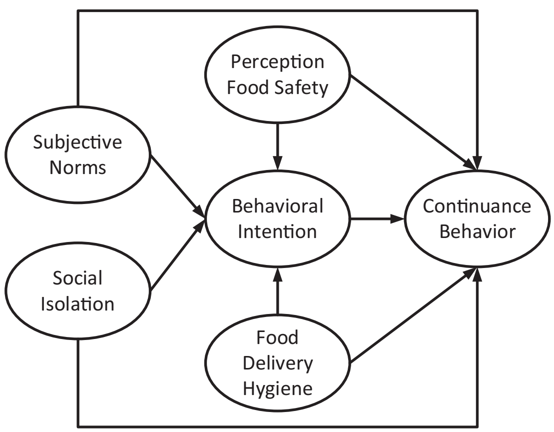

Figure 2.1 Research model.

requirement that they have prior experience with OFD services. The goal number of samples is represented by 370 responses, and this is minimum samples based on 10 times multiply (Hair et al., 2019; Sekaran & Bougie, 2016). The statistical method known as SEM-PLS will be used to analyze the entire hypothesis. The statistical software is known as WarpPLS 8.0 (Kock, 2022; Kock & Moqbel, 2019).

Discussions

It was found that 407 individuals responded to the questionnaire, but only 399 samples were able to satisfy the requirements for moving forward with the process of analysis. These findings were gathered from the outcomes of the distribution of the questionnaire. The demographic information of the respondents is presented in Table 2.1. Women made up the vast majority of participants in this study. Although based on age, it is possible to draw the conclusion that the vast majority of students and young workers are between the ages of 19 and 24, this appears to be the case with a majority that is spread between those ages. The majority of visits and business conducted in a given week take place between two and three times. In addition, the majority of purchases range from IDR 50,000 to 100,000.

After the questionnaire data has been cleaned and altered to meet the study standards, statistical analysis can be performed without compromising the data's original integrity. Partial Least squares was utilized in this study's statistical analysis, performed in WarpPLS 8.0 (Benitez et al., 2020; Kock & Moqbel, 2019). In WarpPLS statistic software, measurement models and structural models are the two main categories (Hair et al., 2012; Kock, 2022; Urbach & Ahlemann, 2010). Each reconstruction will be measured for accuracy and rehabilitation using statistical models. Tabulated in Table 2.2 are the results of the measuring model's measurements, which reveal that the building satisfies the criteria. A framework is shown in Table 2.3. Model fit indicators, R-squared contribution, and effect magnitude for path coefficients are quantified on the structural model. The target value in each evaluation is specified.

The processed hypotheses by WarpPLS are summarized in Table 2.4. If the p-value for a hypothesis is less than 0.05, then it can be considered acceptable (Hair et al., 2019; Kock & Moqbel, 2019). There are two undesirable theories among the nine that have been proposed so far. The p-value for a correlation between food delivery hygiene and continuance behavior is 0.067, and the p-value for a correlation between social isolation and behavior intentions is 0.165; both of these hypotheses are therefore rejected.

Behavioral intention was found to be affected by meal delivery hygiene in this study. This is as a result of the fact that somebody wants to use the online meal delivery service while also paying attention to the hygiene of the food delivery. As far as the consumers' level of confidence in the introduction of foodins' general hygienic measures, such as the donning of masks, and for its preventive measures, as we are able

Table 2.1 Demographic respondents.

Profile respondents	Frequency	Percentage
Sex		
Men	185	46.37
Women	214	53.63
Ages		
13–18 years	44	11.03
19–24 years	127	31.83
25–30 years	79	19.80
31–36 years	43	10.78
37–42 years	43	10.78
Occupation		
Employee	177	44.36
Civil servants	38	9.52
Entrepreneur	26	6.52
Housewives	41	10.28
College students	112	28.07
Frequently visited OFD in a week		
1 time	70	17.54
2–3 times	179	44.86
4–5 times	98	24.56
>5 times	52	13.03
Frequently transaction OFD in a week		
1 time	96	24.06
2–3 times	189	47.37
4–5 times	84	21.05
>5 times	30	7.52
Spending for OFD in a week		
IDR 50–100K	171	42,86
IDR 110—160K	114	28.57
IDR 170–220K	74	18.55
>IDR 220 K	40	10.03

to observe on the application, that is, there is a description of the introduction of foodins' body temperature. As a result of this, customers plan to make use of online meal delivery services in the next years. On the other hand, the impact that is noticed on the continuation of activity reveals that the consumer's intention is not nearly as strong as it might otherwise be. Concerns continue to be raised by customers about the amount of travel involved in the delivery of their orders.

Table 2.2 Measurement model test.

Constructs	Validity test		Reliability test	
	Loading factor	**AVE**	**Composite reliability**	**Cronbach's alpha**
Food delivery hygiene		0.681	0.773	0.607
Gloves on food delivery drivers reassure me.	0.763			
Food delivery drivers that wear masks reassure me.	0.714			
I was informed the driver would wear a cap.	0.537			
When food delivery drivers practice basic sanitation, I feel better.	0.688			
Subjective norms		0.591	0.869	0.835
The online food delivery (OFD) app is recommended by my loved ones.	0.598			
To safeguard myself, my friends recommend ordering food through OFD.	0.666			
People around me use OFD.	0.430			
Friends and family advised me to use the OFD app.	0.706			
My friends and family use OFD also.	0.478			
OFD is favored by most of my friends.	0.621			
OFD users are proud.	0.250			
OFD is trendy.	0.608			
If my friends use OFD, I will too.	0.780			
I used the OFD app as advised by friends.	0.689			
I order food using this OFD app because my friend recommended it.	0.546			
I trust friends and family to approve my OFD transactions.	0.605			
Behavioral intention		0.690	0.862	0.811
OFD apps interest me.	0.740			
I recommend that others allow their neighbors to use OFD.	0.467			
In the future, I'll use OFD.	0.760			
I'll try using OFD in my daily life.	0.744			
I expect to use OFD later.	0.631			
I'll use OFD for important days.	0.744			

(*Continued*)

Table 2.2 (Continued)

Constructs	Validity test		Reliability test	
	Loading factor	AVE	Composite reliability	Cronbach's alpha
Social isolation		0.784	0.863	0.787
OFD apps will increase food evaluation options without face-to-face encounters.	0.636			
To avoid meetings, I order lunch online.	0.818			
I buy food online to avoid face-to-face interaction.	0.857			
The OFD app may increase food testing without face-to-face contact.	0.807			
Continuance behavior		0.720	0.842	0.764
I'll use OFD if I can.	0.707			
I look forward to ordering using the OFD app.	0.578			
I'll use OFD later.	0.723			
I use OFD frequently.	0.784			
I'll keep using OFD.	0.790			
Perceptions of food safety		0.783	0.863	0.788
I trust OFD.	0.705			
OFD makes me feel healthy (no viruses).	0.840			
The OFD app makes me feel clean (no germs or mosquitoes).	0.777			
I trust OFD app food to be parasite- and insect-free.	0.802			

Subjective norms can be defined as a person's impression of how he or she should behave in a certain situation in accordance with the opinion of a person who is close to them. According to the findings of this research, subjective norms have an effect on behavioral intention. This is because a person's intention in using online meal delivery is affected by the opinions of those who are close to him. If you look around you and notice that other people are utilizing the app for online meal delivery, you can be sure that someone else will follow suit. Additionally, if one's family or friends propose and recommend using the internet food delivery service, then one is able to make use of that option. The emergence of this readiness and intention on the part of users to place food orders through OFD services in the future is brought about by this factor.

Table 2.3 Structural model test.

Structural model test	Rules	Results
Model fit indicator		
Average path coefficient (APC)	$p < .05$ Good	0.224
Average R-squared (ARS)	$p < .05$ Good	0.682
Average adjusted R-square (AARS)	$p < .05$ Good	0.678
Average block VIF (AVIF)	AVIF <5 Good	2.005
Average full collinearity VIF (AFVIF)	AFVIF <5 Good	2.518
Tenenhaus GoF (GoF)	Small 0.1−0.24; Medium 0.25−0.35; Large above 0.35	0.587
Simpson's paradox ratio (SPR)	SPR >0.7 Good; Ideal if = 1	1.000
R-squared contribution ratio (RSCR)	RSCR >0.9 Good; Ideal if = 1	1.000
Statistical suppression ratio (SSR)	SSR >0.7 Good	1.000
Nonlinier bivariate causality direction ratio (NLBCDR)	NLBCDR >0.7 Good	1.000
R-squared contribution		
Food delivery hygiene to behavioral intentions	Weak 0.19; Moderate 0.33;	0.027
Food delivery hygiene to continuance behavior	Substantial 0.19	0.019
Subjective norm to behavioral intentions		0.255
Subjective norm to continuance behavior		0.084
Social isolations to behavioral intentions		0.025
Social isolations to continuance behavior		0.070
Continuance behavior to behavioral intentions		0.286
Perceptions of food safety to behavioral intentions		0.144
Perceptions of food safety to continuance behavior		0.083
Effect sizes for path coefficients		
Food delivery hygiene to behavioral intentions	Weak 0.02; Medium 0.15; Large 0.35	0.027
Food delivery hygiene to continuance behavior		0.019
Subjective norm to behavioral intentions		0.368
Subjective norm to continuance behavior		0.084
Social isolations to behavioral intentions		0.025

(*Continued*)

Table 2.3 (Continued)

Structural model test	Rules	Results
Social isolations to continuance behavior		0.101
Continuance behavior to behavioral intentions		0.412
Perceptions of food safety to behavioral intentions		0.208
Perceptions of food safety to continuance behavior		0.120

Table 2.4 Hypotheses result.

Hypotheses	*p*-Value	Path coefficients	Decisions
Food delivery hygiene to behavioral intentions	0.049	0.082	Support
Food delivery hygiene to continuance behavior	0.067	0.074	Not Support
Subjective norm to behavioral intentions	<0.001	0.511	Support
Subjective norm to continuance behavior	0.007	0.121	Support
Social isolations to behavioral intentions	0.165	0.049	Not Support
Social isolations to continuance behavior	<0.001	0.166	Support
Continuance behavior to behavioral intentions	<0.001	0.522	Support
Perceptions of food safety to behavioral intentions	<0.001	0.318	Support
Perceptions of food safety to continuance behavior	<0.001	0.172	Support

It is well known that subjective norms have an effect on the continuation of behavior. One example of this is the decision that consumers make regarding whether or not they will continue to utilize online meal delivery based on the advise of the most important people in their lives. Having friends or family members who support and advocate the usage of OFD services can also be a motivation to make use of these services oneself. As for the factors that contribute to the emergence of a person's willingness and intention to place an order for food through an online meal delivery service in the future, if there is a possibility to do so, if the opportunity presents itself.

One interpretation of social isolation is when a person's response to an urgent situation is to cut back on their level of comprehensive communication. The existence of social isolation did not have an effect on a person's desire to use an online meal delivery app, which meant that the study's findings indicate that social isolation does not have an effect on behavioral intentions. This comment can be used as evidence to show that people who utilize online meal delivery services do not intend to reduce the amount of face-to-face interaction they have. Because of this, one person will not advocate using the app for OFD, and another person will not use the app in the future.

In addition, social isolation has an effect on the continuity of behavior; this means that social isolation affects whether or not the usage of online meal delivery programs is sustainable or inconsistent. This statement provided evidence that, according to consumers, an online meal delivery service can expand the opportunities for testing, evaluating, and even purchasing food without the need for face-to-face interaction. As a direct consequence of this, customers of the online meal delivery service will continue to do so whenever they have the possibility to do so.

The connection between a behavioral intention, which is a person's desire to use an online meal delivery application, and a continuation of behavior, which is a person's intention to continue or stop using an OFD application. A behavioral intention is defined as a person's desire to use an OFD application. The continuity of behavior is shown to be affected by a participant's behavioral intention in this study. This is demonstrated by current users' intentions to utilize the online meal delivery app in the near future. Regarding the factors that influence a user's decision to continue placing orders for meals through an OFD service when given the chance to do so.

The term "perception of food safety" refers to the fact that customers give a considerable deal of attention to the topic of food safety, which encompasses the safety of food packaging, the production processes, and food hygiene. According to the findings of this research, one's impression of the safety of food has an effect on their intentions towards their conduct. This statement can be used as evidence to show that the user feels comfortable and that the food they order through the online meal delivery app is guaranteed to be nutritious. Because of this, current customers intend to keep using the online meal delivery service in the years to come.

In addition, people's perceptions of food safety have an effect on the consistency of their behavior. This is due to the fact that the level of safety that customers observe influences whether or not they continue to use the online meal delivery program. Users of the online meal delivery service report a sense of safety and the assurance that the food they are eating is healthy, which can be demonstrated. As for the reasons why customers will keep using the online meal delivery app, both on the significant day-to-day as well as in the period that is to come, if there is the possibility.

Conclusions

The application service provider can remind food delivery companies that their food delivery providers or drivers can better maintain safety and hygiene standards (food delivery hygiene) in accordance with the rules that are in place when delivering food to consumers, for instance, such as wearing masks and head coverings. This can be helpful for food delivery companies. It is possible that application service providers would benefit from the addition of safety and hygiene requirements reminders within their applications. According to the findings of this study on behavioral intention, the vast majority of respondents said that they planned to make use of online meal delivery applications in the near future. On the other hand, it is not something that is used in everyday life. As a result, businesses should work hard to enhance the quality of service offered by online meal delivery programs. to give consumers a positive experience that will inspire them to utilize an app for OFD both in their day-to-day lives and in the future when they have the opportunity. I would recommend to businesses that are concerned with subjective standards that they continue to give innovation and promote further the benefits of online meal delivery applications to draw the interest of users. Companies can also establish consumer trust by providing services that exceed the expectations of the users themselves as well as evaluating and reviewing the quality of the company's products and services. By doing so, the company not only earns the loyalty of its customers but also creates the possibility of receiving free marketing because those customers can suggest the product to their friends.

Concerning the issue of behavioral continuity, the vast majority of respondents stated that there was absolutely no chance that they would keep using the online meal delivery service on a consistent basis in the future. When it comes to enabling consumers to make consistent use of OFD apps, this might present a barrier for businesses. Advice for businesses, including the provision of services such as the offering of promotions if the number of transactions completed in a given month hits a predetermined threshold. In this way, consumers will have the ability to utilize the online meal delivery service on a consistent basis. According to the findings of this study, people use online meal delivery applications not only to save time and money but also because they do not want to engage with other people in person. This conclusion may be drawn from the study's examination of social isolation. Therefore, it is recommended that businesses place a greater emphasis on prioritizing meal ordering and delivery services that involve absolutely no face-to-face interaction whatsoever. Along the same lines as the cashless and auto message capabilities that allow users to leave their meal at the destination, the company is in the process of innovating and developing this function at all times.

The primary function of the app is to provide users with the option to buy, sample, and review food, this is an effort to make using the app for online meal delivery more easy for those who use it. For the aspect of the restaurant that is associated with the customer's view of the safety of the food, it is recommended to continue to enhance and maintain the hygiene of the food, such as ensuring that it does not include any parasites or insects, beginning with the production process and continuing all the way through to the safety of the packing. Mainly due to the fact that the majority of respondents have stated that they do not believe the claims that the food that can be ordered through the OFD app is safe and clean. This is a very crucial point to bear in mind because it will influence the user's choice on whether or not to use the online meal delivery service, as well as whether or not to continue using the service.

Policymakers in the areas of digital health and IT can do a lot to improve food safety by coming up with new ideas. To make it easier for government agencies, healthcare providers, and people in the food business to share information about food safety, push for the creation of standardized data formats and systems that can talk to each other. You should set aside money to create and use advanced analytics like AI and machine learning so that you can better look at data about food safety. Trends, patterns, and possible dangers can be found faster with these technologies than with older ones. Make sure that food items are tracked and traced all the way through the supply chain using blockchain or a similar technology. This makes sure that everything is clear and that the source of the contamination can be found quickly in case of a spread. Encourage people to use IoT devices and sensors to keep an eye on how food is being stored and transported in real time. This can help keep food safe by stopping it from going bad or getting contaminated. Support the creation of mobile health apps that give people information about food safety, such as real-time recalls, safe ways to handle food, and how to tell the difference between safe and unsafe food items. Strong privacy and data security rules should be put in place to keep private information about food safety safe while still allowing approved parties to share it responsibly. Spend money on public awareness efforts and educational programs to teach people how to safely handle food, why it's important to read food labels, and how to report illnesses that might be caused by food. Work closely with the food business, which includes food producers, distributors, and retailers, to come up with and implement the safest ways to handle food. This could include using IT to keep track of and keep an eye on things.

Businesses in the food industry that adopt and follow modern IT and digital health practices that make food safer should be rewarded or get tax breaks. As food delivery services become more popular, rules should be thought out to make sure that food from places gets to people's homes safely. Digital tools can be used to keep an eye on compliance. Create and regularly update plans for how to quickly respond to outbreaks of foodborne sickness. Digital tools for communication can be very helpful for getting healthcare providers, public health agencies, and the food business to work together. Work with your foreign partners to make sure that food that is brought in or sent out is safe. Standardized IT systems and procedures for sharing data can help with efforts to keep food safe around the world. Check how well digital health and IT projects are working to make food safer on a regular basis and be ready to change rules and laws as technology and risks change. Policymakers can use digital health and

IT to improve food safety, protect public health, and boost customer trust in the safety of the food supply chain by following these suggestions.

The respondents' location in Indonesia, specifically GreaterJakarta and the city that surrounds it, the scope of this study cannot yet be considered comprehensive. In light of the fact that the questionnaire was not as specific as it could have been, it is to be anticipated that additional research will be conducted, albeit using different samples, on the same topic to get data that are more in-depth. It is to be anticipated that in the future there will be study with the same factors by selecting research that is more extensive and having various qualities and advantages. To be more particular and intriguing when being researched or evaluated.

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CHAPTER 3

Technology for early detection and diagnosis of mental disorders: An evidence synthesis

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Introduction

The digital revolution has been growing in many aspects of life especially so in the mental health space. This has particularly been so ever since the global pandemic hit communities, leaving us with no choice but to bow to the fate of technological access that connected us to people and services. With the lockdown and strict social distancing norms, accessing digital platforms to access healthcare services, chiefly mental healthcare, did not just create virtual healthcare accessible but also led to the breaking of stigma predominantly. When it comes to medical care, artificial intelligence (AI) is being used to facilitate early disease detection, enable a better understanding of disease progression, optimize medication/treatment dosages, and uncover novel treatments. However, the discipline of mental health has been slower to adopt (Jiang et al., 2017). Mental health clinicians are more hands-on and patient-centered in their practice than most medical practitioners, relying more on "softer" skills, including forming relationships with patients and directly observing patient behaviors and emotions. Despite this, the potential of AI cannot be denied when it comes to either understanding mental disorders or diagnosing mental disorders. AI techniques have the ability to develop better prediagnostic screening tools and formulate risk models to determine an individual's predisposition for or risk of developing mental disorders (Shatte et al., 2019). It is only till we harness the full potential of computational approaches that mental healthcare can soon be personalized with the help of AI as well.

Mental disorders are the leading cause of disability worldwide (Vigo et al., 2016). Developing countries are disproportionately affected by the burden of mental disorders, largely due to fragmented healthcare systems, scarce mental health specialists and the devastating consequences of poverty and stigma (Becker & Kleinman, 2013). The huge treatment gap of individuals with mental disorders is a concern, up to 90% of

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individuals living with mental disorders in low-resource countries receive no mental health care (Gururaj et al., 2016; Patel et al., 2007). Greater investment in mental health training programs, equipping primary care providers with skills to deliver basic mental healthcare, developing community-based programs, and task-shifting services to lay providers, nonprofessionals, and caregivers (Philip & Chaturvedi, 2018) are promoted but not enough for countries to achieve universal health coverage goals by 2030. Innovative approaches are required for prevention, early detection, timely treatment and rehabilitation of mental disorders. Studies indicate the potential of technology to address mental health concerns (Anthony et al., 2010; Goss et al., 2016; Hategan et al., 2019; Naslund et al., 2017). Some key challenges in the field are diagnosis, treatment and rehabilitation management. Major diagnostic decisions of mental disorders rely on the psychiatrist's clinical evaluation and judgment which is susceptible to misdiagnosis or overdiagnosis (Hairston et al., 2019; Merten et al., 2017). As a result of a delay in accessing mental healthcare, the mental disorder is often in the chronic stage requiring long-term psychiatric intervention and rehabilitation (WHO, 2022). Therefore, early detection of mental health risks, and timely and accurate diagnosis of mental disorders using technology can provide opportunities to reduce treatment gaps. This chapter presents a rapid review of technologies that facilitate early detection and diagnosis of mental illnesses and also provides strengths and limitations in adopting these technologies.

Digital technologies offer effective and timely solutions that scale up and decentralize healthcare across a wide variety of platforms, from teletherapy, mobile health (mHealth) applications, to web-based interventions. They have been used to support mental health services for more than two decades, but the COVID-19 pandemic creates a unique opportunity for greater utilization and more data-driven assessment of these digital technologies in combating the pandemic-driven surge in mental health disorders (Wind et al., 2020). Health promotion is a crucial component of modern healthcare that aims to improve the overall well-being and mental health of individuals and communities. While traditional methods such as education and public health campaigns play a significant role in promoting mental health, technology has emerged as a powerful tool to enhance and expand these efforts. Some of the technological tools for mental health are discussed briefly and largely focus on prevention, early detection and symptom management.

Mobile health applications

mHealth applications have revolutionized mental health promotion by making relevant information, resources and tools readily accessible to individuals. These apps offer features such as symptom tracking, medication reminders, and diet monitoring, enabling users to take charge of their health. mHealth apps can improve medication adherence, manage chronic conditions, and promote healthier lifestyles (Ventola, 2014). They also appear to be a promising self-management tool for reducing depressive symptoms which leads to healthcare professionals holding a favorable view toward the integration of smartphones into clinical practice (Kerst et al., 2020). Additionally, automatic smartphone sensing is a feasible approach for inferring rhythmicity, a key marker of well-being for individuals with bipolar disorder (Abdullah et al., 2016). Hence, raising awareness among healthcare professionals about the advantages of e-health interventions and providing training on the utilization of new technologies could enhance their understanding of mobile applications for addressing mental health issues.

Wearable health devices

Wearable devices, such as fitness trackers and smartwatches that provide real-time data on physical activity, heart rate, and sleep patterns are well known. To add to these, there are bracelets, headgear, and smartphone apps that not only identify symptoms of mental distress but these devices can also respond with immediate feedback and ways to calm down and manage distress. These devices empower users to monitor mental health seamlessly, motivating them to make healthier choices. Jakicic et al. (2016) have demonstrated the positive impact of wearables on physical activity levels and weight management. Studies have looked at the efficacy of wearable devices in identifying symptoms of stress, depression and anxiety by monitoring heart rate and breathing (Hickey et al., 2021). Different devices based on biofeedback can perform varied functions such as touch therapy to calm the nervous system, adjusting daily goals to sleep better and biofeedback data to monitor and improve sleep (Lee et al., 2021).

Telemedicine and telemental health

Telemedicine and telemental health platforms have made mental healthcare services more accessible, particularly in remote or underserved areas. Though this has been an option for a few years, it has been prominently so following the pandemic. Patients can consult with mental healthcare providers through video calls or secure messaging, reducing barriers to care. The World Health Organization (WHO Global Observatory for e-Health, 2010) acknowledges the role of telehealth in promoting overall health equity by ensuring that quality healthcare services are accessible to all. The effectiveness of telemedicine in improving access to mental health services and managing chronic conditions has also been highlighted (Bashshur et al., 2016). Telemental health and telemedicine have seen a mammoth growth from the 1960s, from mere telephonic conversations to internet and web-based consultations as well as delivery interventions.

Health information systems

Electronic health records (EHRs) and health information systems (HISs) have transformed mental healthcare and overall healthcare by facilitating data collection, storage, and sharing among providers. This technology allows for better coordination of care and enables mental health professionals to make informed decisions based on a patient's integrated psychiatric and medical history. Hospital EHR adoption is widespread, and many hospitals are using EHRs to support performance measurement and patient engagement which has resulted in improved patient outcomes and reduced errors (Adler-Milstein et al., 2017). However, this is askew in its infrastructural access with most developing countries devoid of these advanced ways of recording mental healthcare due to economic burden, high costs to maintain EHRs and limited resource availability for mental healthcare in the overall health budget.

Social media and online communities

Social media platforms and online communities have become valuable tools for mental health promotion. These platforms enable the dissemination of mental health information, peer support, and behavior change interventions (Laranjo et al., 2015). There is evidence that social media can influence health-related behaviors, such as smoking cessation and exercise adoption (Laranjo et al., 2015). Social media platforms such as Instagram, X (formerly Twitter) and Facebook can reach the masses and aid mental health advocacy for those who are inaccessible to direct mental healthcare or are unaware of the mental healthcare infrastructure. Several mental health professionals have their professional social media pages which they use to disseminate information and conceptual learning to understand mental health covering a range of purposes, from psychoeducation to simplifying mental health and reaching out to provide care-these measures can also be seen as accelerating access for those who do not have direct access to mental healthcare. For example, websites and chat forums make it convenient for people to "start talking" about their mental health.

Artificial intelligence and data analytics

AI and data analytics have revolutionized health promotion by providing insights into population mental health trends and individualized care. AI algorithms can analyze vast amounts of data to identify risk factors, predict disease outbreaks, and develop personalized treatment plans. Esteva et al. (2017) have highlighted the potential of AI to improve diagnostic accuracy and reduce healthcare costs. AI-powered chatbots have been revolutionizing the space of mental healthcare with the possibility of robot therapy, robots as therapists and AI-powered therapy that can engage individuals with mental distress without human presence and enable them to not just identify symptoms but also provide them with mental healthcare through the means of psychoeducation and cognitive behavioral therapy.

Machine learning

Machine learning (ML) is an evolving field with significant potential to improve the accuracy and efficiency of detection and diagnosis of mental health symptoms or conditions, prediction of mental health risks, and understanding of mental-health-related behaviors. Leveraging diverse data sources and ML models such as support vector machines and deep neural networks, researchers are developing systems that can classify and predict various mental health disorders, offer personalized treatment options, and even detect early warning signs. Thieme et al. (2020) have summarized the primary motivations for using ML in mental health treatment, including the potential benefits arising from the availability of continuously collected and nonintrusive behavioral data, the merits of prompt and automated data processing for increased efficiency and reduced costs and assertions that data-informed evaluations offer greater objectivity, accuracy, and reliability, leading to enhancements in clinical practices and decision-making.

Virtual reality, augmented eeality, and mixed reality

Virtual reality (VR), a technology that immerses individuals in computer-generated environments, has shown significant potential in the detection and diagnosis of various mental health conditions. Augmented reality (AR), on the other hand, overlays digital information on the physical world, providing real-time diagnostic insights. Although AR has received comparatively less attention in mental health diagnosis compared to VR, it has displayed promise in aiding therapists and patients. Mixed reality (Mr) represents a convergence of VR and AR, offering a versatile spectrum of experiences. These technologies collectively offer controlled, standardized, and immersive environments that facilitate the observation of symptoms and behaviors in a secure and replicable manner. They have been proposed as a solution to address the pressing shortage of mental health professionals and the limited accessibility to mental healthcare (Freeman et al., 2017). Consequently, the use of VR, AR, and Mr in the diagnosis and treatment of mental health disorders is on the rise, as evidenced by recent research (Goharinejad et al., 2022).

For example, VR/AR/Mr-based tools have been developed to improve the diagnosis and treatment of children with attention deficit hyperactivity disorder (Usmani et al., 2022), manage eating disorders (De Carvalho et al., 2017), provide exposure therapy for posttraumatic stress disorder (PTSD) (Bell et al., 2022), enhance social and communication skills to boost self-esteem and manage social anxiety (Kim & Kim, 2020), develop environments to successfully treat phobias to some extent (Park et al., 2019), offer cognitive therapy to patients with autism, and test navigational skills and improve cognition in patients with Alzheimer's disease (AD) (Usmani et al., 2022).

Gamification

This is a relatively new trend that focuses on applying game mechanics to nongame contexts to engage audiences and inject a little fun into mundane activities besides generating motivational and cognitive benefits (Sardi et al., 2017). It involves integrating game elements, such as points, rewards, and competition, into health-related apps and programs. By making health promotion engaging and fun, gamification encourages individuals to adopt healthier behaviors. It can have a positive impact on health and well-being-related interventions and the evidence is strongest for the use of gamification to target behavioral outcomes, particularly physical activity (Johnson et al., 2016).

Applications of health technologies

We have identified communications programming, ML, and AI as technology platforms and ML tools, telecommunication, mobile applications, and web-based online applications that are used as tools for early detection, diagnosis, treatment and management of mental ailments. These technologies primarily target mental illnesses such as depression, anxiety, schizophrenia, substance misuse, dementia, epilepsy, and Alzheimer's.

Machine learning tools

Mental health diagnosis is being supplemented by machine-learning tools, which automatically expand their capabilities based on new data. Virtual robots-based programs have been based on early detection, diagnosis and treatment of mental illnesses.

- Quarter Health (2022) screens patients' medical histories and behavioral patterns to uncover undiagnosed mental health problems. For instance, Quartet can flag possible anxiety based on whether someone has been repeatedly tested for a nonexistent cardiac problem.
- Woebot (2023) is a chatbot developed by clinical psychologists at Stanford University in 2017. It simulates human conversation, either through text or a voice-enabled AI interface. It treats depression and anxiety using a digital version of the cognitive behavioral therapy technique —highly structured talk psychotherapy that seeks to alter a patient's negative thought patterns in a limited number of sessions. In a study (Fitzpatrick et al., 2017) conducted with university students who were diagnosed with depression, the use of Woebot facilitated a 20% improvement in just two weeks. Patient engagement is one of the primary reasons for Woebot's success with the study group.
- Wysa (2023) is a playful AI penguin that operates on iPhone and Android platforms. Based on patients' responses, Wysa built a "toolkit" with a variety of exercises. Some of these exercises are based on the practice of mindful meditation, which is an Eastern-influenced and evidence-based approach to managing a variety

of psychological issues, especially stress and anxiety. Wysa is very user-friendly, attractive, and easy to use.

- Joyable (2023) is an online platform that supports users with a dedicated real-life coach and a two-month course in CBT. Joyable begins with a structured assessment that helps users identify issues to work on. Also, it collected feedback immediately after the assessment, which included the expected reduction in symptoms. After my two-month program, a decrease in depressed mood was anticipated.
- Talkspace (2022) provides online therapy with a licensed health professional at a significantly reduced rate. Similar to Joyable, it uses a variety of activity-based tools to make improvements in a variety of areas such as happiness, compassion, balance, self-awareness, and productivity. Users can communicate with therapists by leaving text, audio, and video messages at any time.
- SimSensei (2023) and Elie (2023) are both ML based tools developed by the University of Southern California's Institute for Creative Technologies. As part of the Detection and Computational Analysis of Psychological Signals project, they have used AI, natural language processing and computer vision to identify indicators of psychological distress such as depression, anxiety and PTSD, known as SimSensei. They have integrated ICT (information communication technology) virtual human therapist, Elie, to provide mental healthcare support. Ellie can determine her questions, motions, and gestures; detect nonverbal cues and respond accordingly. For instance, she has learned when to nod approvingly or perhaps utter a well-placed "hmm" to encourage patients to be more forthcoming. The program observes 66 points on the patient's face and notes the patient's rate of speech and the length of pauses before answering questions. Ellie's actions, motions, and speech mimic those of a real therapist—but not entirely, which is an advantage with patients who are fearful of therapy.
- Functional magnetic resonance imaging (fMRI) (Kalmady et al., 2019). Researchers at the National Institute of Mental Health and Neurosciences (NIMHANS), Bangalore have built a model that could predict schizophrenia with an accuracy of 87% using fMRI. The model has been named "EMPaSchiz" or "Ensemble algorithm with Multiple Parcellations for Schizophrenia prediction."
- Lightweight biosensors (Karstoft et al., 2015). Ambient assisted living can facilitate optimum health and wellness by aiding physical, mental and social well-being. Patients' psychiatric symptoms are collected through lightweight biosensors and web-based psychiatric screening scales in a smart home environment and then analyzed through ML algorithms to provide ambient intelligence in a psychiatric emergency. The psychiatric states are modeled through a hidden Markov model, and the model parameters are estimated using a Viterbi path counting and scalable stochastic variational inference-based training algorithm. The most likely psychiatric state sequence of the corresponding observation sequence is determined, and an emergency

psychiatric state is predicted through the proposed algorithm. Moreover, to enable personalized psychiatric emergency care, a web of objects-based framework is proposed for a smart-home environment. In this framework, the biosensor observations and the psychiatric rating scales are objectified and virtualized in the web space. Then, the web of objects of sensor observations and psychiatric rating scores are used to assess the dweller's mental health status and to predict an emergency psychiatric state. The proposed psychiatric state prediction algorithm reported 83.03% prediction accuracy in an empirical performance study.

- A team led by Theodore D. Satterthwaite (Xia et al., 2018) mapped abnormalities in brain networks to four dimensions of psychopathology: mood, psychosis, fear, and disruptive externalizing behavior.
- The Mental Motion State Model (Zhang et al., 2017), trained by applying the Gaussian mixture model to electroencephalogram data, can indicate degrees of engagement and fatigue levels, providing a feedback channel for self-regulation.
- Neuroimaging techniques such as MR, computed tomography (CT), single photon emission computed tomography (SPECT), and positron emission tomography (PET) have been used to assist in the diagnosis of AD (Scheltens, 2009). In a study cited by Knopman and colleagues (McKhann et al., 2011), CT scans were 95% sensitive and 40% specific for diagnosing AD; the SPECT results revealed sensitivities ranging from 86% to 95%, and specificities ranging from 42% to 73 and PET scans were reported to have a sensitivity of 93% and a specificity of 63%. Knopman and colleagues (Frisoni, 2001) cautioned that imaging should be used in conjunction with other tests to increase the likelihood of an accurate diagnosis. Only noncontrast CT or MRI scans were recommended for use in routine initial evaluation of dementia patients.
- Neurotrack (2024) utilizes ML and AI in its cognitive assessment and brain health tracking processes. It has concluded a successful clinical study on at-risk patients of dementia. Neurotrack's 5-minute imprint memory assessment involves patients viewing various images and then utilizes eye movement tracking to generate a comprehensive memory evaluation. Subsequently, it provides tailored recommendations for exercises and lifestyle adjustments to maintain memory health. Users have the option to retake the test every three to six months to monitor their progress and compare their initial data with individuals of similar age. Clinical research indicates that those employing this method experience an overall enhancement of 25% in memory, an 83% boost in executive functions, and a remarkable 150% improvement in the processing of new information.
- The utility of the levels of amyloid beta (Aβ) peptide and tau in blood-based biomarkers has the potential for diagnosis of AD (Lue et al., 2017). Currently, the potential of utilizing these technologies to advance Aβ and tau as blood-based

biomarkers for AD requires further validation using already collected large sets of samples, as well as new cohorts and population-based longitudinal studies.

- Marr (2019) is a parental control phone tracker app using ML that allows parents to monitor content, manage screen time and filter websites while their children are online to prevent issues such as such as cyberbullying, suicidal ideation, and school shooting threats. When the app detects a concerning issue (red flag), it notifies parents by sending them alerts and also offers expert guidance and recommendations to address the issue and diffuse the problem. Bark is rated to be the best app across all existing apps when it comes to providing the best overall parental control.
- Marr (2019) offers immediate counseling services through a chat application that members can access instantly. The platform analyses the language patients use to seek assistance, enabling a better understanding of their situation. It then suggests the most suitable approach for emotional health coaches. Ginger's algorithms have been trained using an extensive dataset, including over 2 billion behavioral data samples, 2 million clinical assessments, and 45 million chat messages, to provide tailored recommendations for various situations. This chat application primarily targets employers, offering comprehensive subscription packages for their employees, and it commits to a 70% improvement rate in users' conditions within 8–12 weeks. BuzzFeed, Pinterest, and Sephora are some of its notable customers.

Wearables and smartphones may soon be able to help people who suffer from depression, bipolar disorder, schizophrenia, suicidal thoughts, and other disorders by monitoring their activity, physical symptoms, and social interactions for early warning signs of trouble. The physical and physiological dataset, collected by the wearable device, can further be used as an additional input by physicians to determine the existence of depression and its current stage. This data input also helps in reducing the risk of misinterpreting diagnosis.

Abilify MyCite (Flore, 2021), developed by Otsuka America Pharmaceutical and Proteus Digital Health, is used to treat schizophrenia and bipolar disorder and as an adjunct for depression in adults. A sensor in the pill lets a patch the patient wears on his torso know when it's been ingested. This is under review by the United States Food and Drug Administration. If approved, this Digital Medicine would securely measure patient medication-taking patterns, as well as select physiological data and self-reported behavioral information. It can be useful in assessing patient behavior to better inform diagnosis and assess drug adherence.

Abdullah and Choudhury (2018) have proposed a new sensing technology system that uses wearables and smartphones to capture a variety of behavioral, physiological, and social data to detect mental illnesses. Table 3.1 details the sensing methods, types of technology required, data features, and the types of patients most helped by the method.

Table 3.1 Technology systems to capture behavioral, physiological, and social data to detect mental illnesses.

Type of technology	Key measurements	Relevance to mental illnesses
GPS, Bluetooth, WiFi	Assess behavioral signals such as distance traveled, circadian movement, radius of gyration, routine index, and location cluster	Depression, bipolar disorder, anxiety disorders and schizophrenia
Microphone in phone and smartwatch	Assess behavioral signals like voice features, speaking cues, conversation frequency and duration	Depression, bipolar disorder, schizophrenia, and suicidal ideation
Smartphone	Assess behavioral signals like duration and frequency of phone and app use	Depression, bipolar disorder, and schizophrenia
Accesometer and gyroscope in phone and smartwatch	Assess behavioral signals like sedentary duration, activity type such as running, walking and its duration	
Camera in smartphone	Assess physiological signals such as facial action unit, facial expressivity	Depression, suicidal ideation and schizophrenia
Smartwatch or smartphone	Assess physiological signals like anomaly and variability in heart rate	Schizophrenia, bipolar disorders, posttraumatic stress disorder (PTSD), and anxiety disorder
Camera in smartphones	Assess physiological signals like blinking and oculomotor performances	Schizophrenia, depression, and dementia
Smartwatch	Assess physiological signals of electrodermal activities like amplitude, rising time, and habituation rate	Schizophrenia, bipolar disorders and suicide risk
Bluetooth and Wifi	Assesses social signals like proximity and co-location	Schizophrenia and bipolar disorders
Smartphone	Assesses social signals like calls and SMS	Depression, bipolar disorders, and schizophrenia
Social media like X (formerly Twitter), Facebook, and Instagram	Textual and image content and engagement	Depression and PTSD

Telehealth systems and telemental health technologies

The use of modalities involving the telephone, internet and videoconferencing appears to be feasible in diagnosing mental illnesses. Telehealth system is used for providing both diagnosis and treatment services in resource constraint context. Currently, telemental healthcare offers capabilities for imaging, synchronous and asynchronous psychotherapy, and consultation to clinicians in a variety of settings (Bashshur et al., 2016; Langarizadeh et al., 2017)

Videoconference, telephone and text messages (e-mails and chats) are gaining popularity as a modality to provide assessment and treatment services for mental illnesses (Hilty et al., 2018) From a public health perspective, these technologies have the potential to reach out to people residing in remote and hard-to-reach places and facilitate access to mental health services by mental health experts. However, using these technologies only for diagnosis can be an expensive affair.

Web-based services can offer live opportunities for self-assessment of early symptoms and risk of mental illnesses. Lately, many online programs are designed to disseminate information about mental health and peer-led emotional support systems where clients talk with listeners (who are not lay mental health service providers) who listen to clients and provide basic emotional support without paying any charges. Such service providers are SevenCupsofTea (2021), YourDost (2023), and MoodCafe (2023) and in addition, they also provide a platform to identify counselors or psychologists or psychotherapists for specialized mental health support on a payment basis through video or audio or chat. Further few AI-based automated online self-assessment tools are available that help people anonymously assess mental health status. For example, Flore (2021) and various universities offer free online anonymous self-assessment tools such as the University of Massachusetts medical school offers such services. These platforms are also used to promote information transfer and communication among clients and clinicians.

Strengths and limitations of technology

Alan Turing's philosophy focuses on how AI imitates human actions, emotions, speech, and decision-making (Noel Sharkey, 2012). While AI can provide accurate responses based on available data, it lacks the expansive abilities of humans. Humans can imagine, anticipate, feel, and adapt to changing situations, allowing them to shift from short-term to long-term concerns. This uniqueness arises from the human capacity to work without a constant stream of externally provided data, which is required by AI (De Cremer & Kasparov, 2021). Similarly, technologies have the potential for early detection, prevention, diagnosis, and treatment of mental illnesses. The digitization of mental health services is impersonal, the inherent anonymity of AI turns out to be a positive. Technologies have the potential for early recognition of mental health problems, ensuring timely and accurate diagnosis, speeding up the needed treatment, and improving the odds of positive outcomes. However, certain concerns related to effectiveness, ethics, and costs still remain. Further research is needed to rigorously evaluate effectiveness, assess costs, and carefully consider potential risks of health technology.

AI excels at tasks like multitasking, computation, and memory retention, but it falls short in various aspects that contribute to comprehensive intelligence. These include linguistics and natural language processing, creativity, intuition, logical reasoning, artistic ability, exception handling, experimental learning, deliberation, and emotional intelligence (Komal, 2014). Additionally, AI lacks qualities like intuition and cultural sensitivity, and it struggles in situations requiring emotional intelligence, such as interpreting facial expressions and managing emotional communication in relationships (Bhattacharya, 2022).

Furthermore, the intricacy of human emotions presents a fundamental reason for the superiority of human intelligence in the field of mental health. While technology can process data and identify patterns, it often struggles to decipher the nuances of emotional expression. Professor Paul Ekman's research has highlighted humans' exceptional skill in detecting microexpressions and subtle emotional cues, which are vital for the early detection of mental distress (Flore, 2021). Though this may be a possibility for AI and technology-driven healthcare, it is still only nascent and inconclusive (Lodha, 2018). Human intelligence also excels in comprehending the broader context of an individual's life and experiences. Humans uniquely integrate information from all their senses—sight, hearing, touch, smell, and taste—to form a coherent understanding of their surroundings and circumstances, enabling quick and efficient decision-making. In contrast, most AI systems are unable to learn in this multimodal way (Bennett, 2023).

When it comes to technology used in diagnosis and treatment, ethical and privacy concerns are significant. Human oversight is necessary to address these issues adequately. Additionally, bias can enter AI at various stages, including data collection, preparation, and problem framing. As a result, AI-powered health tools require distinct regulatory evaluations due to their diverse applications (Martinez-Martin, 2022). Conclusively it can be agreed that though AI and the current wave of technological development have a promising output for mental healthcare, it is still a dream to have ethically informed and culturally sensitive bot-therapists that can replace human therapists. Thus, the potential of technology must rather be integrated with human intelligence in order to harness the benefits of technology in mental healthcare.

National-level integration and capacity building for digital healthcare

Tackling global health challenges demands the appropriate use of available technologies. The evidence of the benefits of digital health for improving the performance of health systems and outcomes is rapidly growing but also limited to that in developed countries with significant gaps in resource-constrained areas and low and middle income countries (LMICs). Technological and socio-cultural disparities between different regions or between provinces within the same country are prevalent. Thus, there is a need for programs to be responsive to the needs of all relevant regional stakeholders, societies, and communities (Curioso, 2019).

With the rapid digitalization of healthcare, there is a need for capacity building of stakeholders, training and upskilling of technicians and clinicians on digital technology, building the know-how to keep up to date with technology, instating guidelines to navigate through ethical and legal concerns regarding digital healthcare for all and ensuring the equitable distribution and access of digital mental healthcare for all, across regions.

Strong leadership and stakeholders along with governance are crucial for coordinating digital health initiatives and building capacity for digital health opportunities. It is equally important that countries and organizations have a strategy for capacity building that is appropriate to the needs and status of the HIS. Training and workshops can help to implement national digital health strategies and plans, including the capacity to evaluate the impact of the strategies; ensuring and increasing digital literacy and advocacy to disseminate awareness of mental health as well as digital health regulations and governance to ensure sustainable and long-term development in mental health systems are the tenets to integrate digital mental healthcare at a national level.

The aim should be to appropriately adopt digital health technologies for mental health within the context of the national health sector and health strategies that are pertinent to the needs and demands of the country. The global strategy acknowledges that each country owns its digital health action plan built on the strategy, within its own national context. To realize their potential, digital mental health initiatives must be part of the wider health needs and the digital health ecosystem and guided by a robust strategy that integrates leadership, financial, organizational, human and technological resources and is used as the basis for a cost action plan which enables coordination among multiple stakeholders. The strategy should address an approach that will work across public health priorities underpinned by standards and an architecture that enables this integration (Global Strategy on Digital Health, 2020–2025).

Need for policy

The responsible use of technologies necessitates the development and implementation of comprehensive policies with a focus on the following.

Ethical guidelines and data privacy considerations

The advancement of technology in the realm of mental healthcare brings with it ethical and digital privacy considerations that heighten the risk of inadvertent breaches of confidentiality. Technologies including both the direct delivery of services and ancillary support, such as email communication, text messaging, telepsychology and telemental health therapy, electronic medical records, cloud-based storage, apps, and assessments, have the potential to compromise the safety and ethical dimensions of technology applications (Lustgarten et al., 2020). The formulation of clear policies is imperative to effectively address concerns pertaining to informed consent, data security, and patients' rights in relation to their personal information.

Quality assurance and standardization

To ensure the quality of care, technology-driven mental health services need policies that standardize diagnostic and treatment protocols. Standardization can help in defining best practices, ensuring that technologies used meet specific quality benchmarks, and guaranteeing that healthcare professionals adhere to ethical guidelines.

Data integrity, regulatory frameworks, and clinical oversight

The reliability and accuracy of data ar a critical components for ensuring patient trust, clinical decision-making, maintaining confidentiality, and provision of high-quality care. Establishing clear lines of accountability and creating regulatory frameworks can prevent misuse and malpractice of the data while encouraging responsible innovation. For example, the comprehensive App Evaluation Framework is a useful tool to evaluate applications in many relevant areas using five levels of examination: accessibility and background, privacy, safety and security, clinical foundation and evidence base, usability and data integration toward the therapeutic goal (Torous et al., 2018). However, a lack of transparent reporting can impede individuals from accurately assessing these five levels. Therefore, Rodriguez-Villa and Torous (2019) propose the use of a self-certification program, supported by policymakers, clinicians, and clients, for developers, in addition to the approach (Van Daele et al., 2020). Effective policies should also delineate the roles and responsibilities of healthcare professionals, technology providers, and regulatory bodies.

Conclusion

The rapidly evolving landscape of mental health technology offers substantial promise for the early detection and diagnosis of mental illnesses since the amalgamation of information and communication technologies, networked health systems, and cutting-edge diagnostic equipment has shown potential to extend the reach of mental health services to underserved populations and bridge crucial gaps while providing seamless and continuous care. This chapter has provided an overview of diverse mental health technology applications, however, it is essential to acknowledge the nuanced strengths and limitations in technology adoption for mental healthcare. Thus, further research and a strong political commitment leading to the formulation and implementation of policies for regulating and guiding integration of technology as well as to thoroughly assess the effectiveness, evaluate costs, and comprehensively explore the potential drawbacks is imperative.

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CHAPTER 4

Critical analysis of digital mental health applications for healthy aging

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Introduction

An increase in life expectancy has led to the desire to stay healthy and active, and participating fully in life has been on the rise. It is estimated that the worldwide growth of people aged over 60 years will be at least 2 billion by 2050 (Buyl et al., 2020). Contrary to popular belief that elders are a burden to society, many of them contribute constructively through volunteering, childcare, continued work, and household work. However, they face disabilities as they age, ranging from minor difficulties, gradually leading to significant impairments (Reynolds et al., 2022). The decline in physiological, cognitive, and biological systems natural to aging impacts the intellectual, cultural and social involvement in older persons (Buyl et al., 2020).

The World Health Organization (WHO) recognizes aging of the population as one of the greatest triumphs yet the greatest challenge, emerging from the socioeconomic demands on communities and healthcare systems. The World Health Organization's active ageing model is based on the optimization of four key "pillars": health, lifelong learning, participation, and security. Proposed first in 1997, active aging allows people to realize their potential for physical, social, and mental well-being throughout their life course and to participate in society according to their needs, desires, and capacities while providing them with adequate protection, security, and care when they require assistance (Robbins et al., 2018). Enabling active aging gives an opportunity to overcome the challenges of this population. It allows aging to be a positive experience for individuals, communities, and society at large. Active aging serves as an umbrella term, incorporating healthy and successful aging (Robbins et al., 2018).

Healthy aging (HA) is defined as "the process of optimizing opportunities for physical, social, and mental health to enable older people to take an active part in society without discrimination and to enjoy an independent and good quality of life" (Buyl et al., 2020). It provides an opportunity to actively engage with life, in spiritual, physical, social, and cognitive capacities.

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Successful aging has been defined as a low probability of disease, high cognitive and physical function and active engagement with life. Wisdom has also been identified as a feature of positive aging (Reynolds et al., 2022; Robbins et al., 2018). In a broader sense, successful aging is indicated through subjective well-being with low levels of stress, flourishing in close social relationships and meaning of life, posttraumatic growth, sustained recovery from mental disorders along with independence in functioning (Reynolds et al., 2022; Robbins et al., 2018).

Digital health and digital mental health

Digital change has been rampant in the last two decades, but particularly challenging in healthcare, as there is growing demand for services due to the aging population and the emergence of new diseases. Digital health is commonly interchangeably used with the term, e-health, though there is not much difference between the two, a point of difference to note is the breadth of technologies covered by both. Digital health refers to the use of information and communications technologies in medicine and other health professions to manage illnesses and health risks and to promote wellness. There has been a growing development of information and communication technologies being used by the older population making health interventions more accessible and easier to use. The potential of digital health initiatives to empower, encourage, educate, and engage older adults is immense and has caught the attention of many researchers (Buyl et al., 2020). The four common practices in digital health include mobile health (mHealth), telehealth/telemedicine, technology and others. Digital interventions are promising in their ability to provide researchers, medical practitioners, and patients with a dynamic and individualizable tool for assessing behavior and behavioral change, consultation, treatment, and integrated care (Seifert et al., 2019). These digital interventions can help patients manage their diseases or their general health as a form of disease prevention. This is particularly important in older people, as individuals often have to deal with highly complex interactions involved in managing their daily lives along with the consequences of a multitude of chronic diseases (Marengoni et al., 2011). Digital interventions can, for example, assess, control, and positively influence mental health and well-being among older patients (Ploeg et al., 2017).

Worldwide, over 20% of the elderly suffer from some mental health challenges (WHO, 2017). Thus, alongside physical health concerns, mental health is also a key contributor to overall well-being in the elderly population. Mental health challenges, most commonly, anxiety disorder, cognitive impairment, or a mood disorder, often contribute majorly to the disabilities the elderly face comorbid to physical ailments, (Buyl et al., 2020). Technology is being seen as a solution for mental health needs not only for younger but also for older adults. It has been adopted by older adults to manage social isolation and access vital health services, especially during the COVID-19 pandemic (Riadi et al., 2022). However, it must be noted that the issue of the digital divide is real, not everyone has access to the internet. Global statistics reveal that the internet penetration is at 64.60% (Statista, 2023) at a global level and that digital health is also thus, unevenly distributed, especially askew for the low and middle income countries and regions with limited resources for digitalization. Though the elderly have the risk of being excluded from using digital mental health interventions for various reasons (from lack of digital know-how to investing greater effort to learn technologies), there are still benefits of digital mental health interventions that can apply to the elderly as there is a growing number of elderly using the internet and digital platforms, and there is a greater interest of elderly integrating technology in healthcare. In the further sections, some media of digital mental health interventions are discussed.

Digital applications for healthy aging

There is a gap in mental health services and this disparity stems from the shortage of available professionals, lack of accessibility, and overall increased burden of mental healthcare which gives rise to the "treatment gap." Digital health initiatives help to bridge this gap, thus making it viable for individuals looking to cater to their mental health needs. It helps reduce the ambivalence towards mental health as a concept and allows users, young and old, to engage in their well-being at their own pace (Tong et al., 2022).

Digital health applications encompass a wide range of technologies and interventions, using e-platforms to promote holistic well-being among older adults and have various types. Examples of successful digital health applications for mental healthcare and health promotion are telemedicine, electronic health records, virtual interventions, and personal health monitoring. Advances in digital health support disease management, cater to specific needs for active aging and improve autonomous living and mobility through smart devices. There are applications designed for virtual exercises, networking, active lifestyle, and independence that have seen a positive response from this population (Buyl et al., 2020). Physical healthcare aids mental healthcare which overall makes holistic health and aging better. Digital applications for mental healthcare, including websites, web blogs, chat forums, mobile applications and other digital interventions provide various ways to take care of the mental health of the elderly. Digital technologies have been able to build user-friendly features such as sending reminders, quick and live interaction with mental health professionals, scheduling appointments, accessing meditations and accessing audio-visual material for psychoeducation and distress relief.

Telemedicine and telehealth

Telemedicine is the delivery and facilitation of health and health-related services using digital communication technology, where distance is a critical factor demanding remote medical practice. It involves the exchange of accurate information on diagnosis, treatment, prevention of diseases as well as injuries, health information, patient education, research, and training. For over 2 years, synonymous terms like telehealth, digital health, telecare, etc. have been used for telemedicine (Kalaivanan et al., 2021).

Recent Telemedicine Practice Guidelines (2020) identify using images, documents, text messages, audio, and/or video calls as appropriate and approved means to deliver healthcare services as part of telemedicine. With the rise of expenditure in the healthcare sector, using video calls and internet applications makes healthcare affordable and accessible to many, especially the elderly who may not be able to physically visit centers as frequently. Most of these recent treatment options do not have many side effects, require lesser monitoring and have seen a reduction in review visitations (Kalaivanan et al., 2021).

Wearable devices

Technology worn on the body (wearables), such as smartphones, smartwatches, and wristbands, include a variety of sensors that support new methods for continuous monitoring of biological, behavioral, or environmental data, delivering interventions, and assessing their outcomes. These sensor systems include accelerometers, gyroscopes, magnetometers, barometers, sensors which are required for the measurement of heart rate and galvanic skin response, cameras, as well as geo-sensors (global positioning system (GPS)) for tracking one's exact geographical position (Helbostad et al., 2017). These sensor systems, provide highly precise information over time, constantly and instantly. They are well suited for delivering digitized interventions, along with self-assessment of behavior. The development of algorithms helps attain new information about emotional, environmental, physiological, and psychological states through sensor-derived data. Additional self-reported data can help with this as well (Helbostad et al., 2017). Wearable sensors offer real-time body monitoring of health and behavior. These devices are of four kinds, namely physical sensors, chemical sensors, hybrid sensors, multiple parameters sensing platforms, and nonwearable sensors (Chen et al., 2023). Wearable sensors are devices that measure physical signs of the human body constantly over long periods of time. These include heart rate, body temperature, respiration rate, oxygen saturation, blood pressure and electrocardiogram. They monitor mobility using miniature motion sensors and can detect fall events and even assess gait disorders. This continuous monitoring helps identify trigger warnings of adverse or deteriorating conditions (Chen et al., 2023). For the elderly, there are several helpful such devices, viz., heart-rate monitoring devices, blood pressure monitoring devices, glucose monitoring devices, fitness trackers, fall detection and alert devices smart-watches with senior-friendly features (can provide medication reminders, hydration alerts, and emergency SOS functions), GPS tracking devices that come in very handy for those seniors with cognitive impairment or related disorders such as Alzheimer's and dementia, medication management (MM) devices (especially for multiple medications), sleep tracking devices, hearing assistive devices, personal emergency response systems(to provide immediate assistance to senior citizens in case of emergency which connects them to emergency services).

Wearable chemical sensors are noninvasive, capturing rich chemical molecular data in real time. These help track the dynamically changing chemical composition of body fluids like sweat, saliva, tears and hormones which helps gain a clearer diagnostic picture of the user's health conditions (Chen et al., 2023). Multisensor devices combine the functions of physical and chemical sensors to provide a holistic picture of an individual's health. They are usually connected to other devices like smartphones and tablets to collect and transmit data, providing a continuous flow of data to healthcare providers. Nonwearable sensors are based on smart digital homes using cameras and other devices fixed in the house to detect any anomaly in behavioral postures or movements of older adults (Chen et al., 2023).

Mobile health applications

mHealth focuses on the delivery of healthcare services through mobile devices. WHO describes it as medical and public health practices supported by mobile devices such as mobile phones, patient monitoring devices, personal digital assistants (e.g., Alexa and Siri) and other wireless devices. It is based on the use of wireless mobile technology that can be carried, accessed, or worn during daily activities (Helbostad et al., 2017).

There are several types of mental health applications which are either self-guided, unguided, self-supported or fully automated in nature. Guided apps are used with the support of a healthcare professional. Fully automated apps are those not need any human support and are entirely dependent on self-use. Blended concepts are also on the rise, wherein elements of face-to-face interactions and digital interventions are used, incorporating the use of mobile applications. In blended therapy, smartphone applications are used as only part of the treatment plan with the main aim to support and augment face-to-face therapy (Tong et al., 2022).

Synchronous and asynchronous therapy can be availed through phone calls, videoconferencing, and messaging. Computer-based, web-based, and mobile delivery of therapy programs; virtual or augmented reality (AR)-based programs; computerized or web-based cognitive training, and online peer and social support groups are also gaining popularity to make mental healthcare accessible and inexpensive (Philippe et al., 2022).

There are more than 20,000 apps for mental health; more and more apps are receiving funding to support their development. While apps have gained wide acceptance for uses such as coaching, mindfulness or relaxation, the world of app-based mental health intervention has been plagued by a number of issues including inconsistent quality, challenges with engagement, absence of regulation, and significant concerns about privacy and security of user data (Carlo et al., 2019). These challenges seem to be particularly problematic for apps designed for use by older adults (Portenhauser et al., 2021). As such, as a result of the novelty of digital psychiatry as a field, there is emerging consensus that mental health apps may have a relatively confined role and modest impact in delivering mental health interventions, especially to older adults. Their efficacy and acceptability to users is greater when the apps are provided in conjunction with a human coach or therapist.

Digital cognitive training

Computerized cognitive training (CCT) is one approach to intervention design with a focus on improving specific aspects of cognition. Feasibility studies on CCT have been shown to improve memory, reasoning, self-control, processing speed and attention bias. CCT has successfully been applied in clinical research to manage psychological illnesses and cognitive deficits in disorders such as neurodegenerative diseases, dementia, depression, attention-deficit/hyperactivity disorder, and brain injury. The most common CCT task is the Go/No-Go task, in which participants are asked to inhibit responses under changing conditions (e.g., in a fast-paced task, the user may be asked to press L when a red box appears and avoid pressing L when a green box appears). Other tasks are memory training, and the Attention Bias Modification Training (ABMT) task (Birk & Mandryk, 2019). A metaanalysis of CCT in older adults showed that CCT is able to improve overall cognitive function, memory (verbal, nonverbal), processing speed, working memory and visuospatial skills (Lampit et al., 2020).

Medication management apps

Approximately 88% of older adults are living with one or more chronic conditions (physical or mental) which require taking regular oral medications. Managing pill taking is a key component of health self-management and failing to adhere to the proper medication regimen can increase hospitalization and health costs or lead to negative drug effects from over or under-dose. Older adults are likely to be irregular with their medications due to a limited ability to read and understand vital health information, or reduced memory ability associated with aging (Stuck et al., 2017).

A reliable and easy-to-use medication management (MM) tool helps patients' compliance with the prescribed. Users can also have to Take multiple medications simultaneously, integrate the medication into their daily routine at the right time, understand the effects and side effects of medicines, or gain information about medication safety and efficacy (Tabi et al., 2019). The ease of using mobile phones and the accessibility of these devices help increase medical adherence and engagement with personal well-being. These apps also provide opportunities to personalize solutions for the unique goals associated with MM (Tabi et al., 2019).

Virtual reality applications

Technologies such as virtual reality (VR) and AR have been the areas of interest in research due to their potential to assist older adults in monitoring and maintaining their health and improving their quality of life. Many studies of older adults have addressed the potential of VR and AR applications to enhance the physical and cognitive activities of older adults, improve their social support, engage them in activities, and motivate them in training programs. Researchers have conducted a systematic review of the literature on the potential applications of VR and AR for older adults and found the primary applications of VR and AR in healthcare are for rehabilitation, fall prevention, physical activities, cognitive training, entertainment, and virtual travel purposes (Baragash et al., 2022).

Purpose and application of digital health applications for healthy aging

Across the globe, digital mental health care has potentially been reaching billions of people with access to the internet, especially more since COVID-19. The online and mobile delivery of mental health services like therapy saves practitioners time due to the efficient and effective delivery of services at lower costs. Digital mental health interventions also offer a reduction in care interruptions while allowing practitioners to adhere to safe social distancing measures. Mobile applications are increasingly being used by people for the treatment of mood and anxiety disorders, sometimes even without professional referral or guidance (Philippe et al., 2022).

There is some evidence that web-based forums and resources have become increasingly common and preferred by people. The last 10 years have seen noticeable shifts in the provision of cognitive and behavioral training for developmental disorders and dementia to computer and other web-based platforms with significant developments being made in the application of VR tools in healthcare settings (Philippe et al., 2022).

The leverage of technology to support the well-being of older adults is on the high. Applications utilize digital platforms like mobile applications, wearable devices, and telehealth services to address unique health challenges. Some uses of digitalized mental health for HA are discussed below.

Health monitoring and management

To serve the elderly population, home-based care has always been a practical and well-liked option due to many reasons. Many elderly individuals are weak, and a sizable percentage of them might only live with their spouses, making plans for medical visits could be mentally exhausting and upsetting for the entire family if children are not seeing their elderly parents. Although repeated visits to healthcare institutes may be necessary due to the requirement for frequent evaluation and monitoring, not all of them result in significant management changes other than a minor adjustment of medicine dosage, ordering, and evaluating investigations. As a result, older persons visit emergency rooms more frequently than they do ordinary outpatient departments (OPDs). With the aid of tools like digital blood pressure monitors, glucometers, entry-level pulse oximeters, and weighing machines, self-monitoring may now be done at home. To prevent emergency visits and improve OPD visits, home-based self-monitoring and telemedicine can be combined to enhance medical consultations (Kalaivanan et al., 2021).

Remote consultations and telemedicine

The quality of life is impacted by mental health problems, which are also linked to high morbidity and raise mortality. As is always the case, providing high-quality care is significantly hampered by the shortage of experts and qualified staff in geriatric mental health. The District Mental Health Program and other community programs run by nonprofit groups are widely implemented, but the demand is still high, making it difficult to reduce the treatment gap. Accordingly, embracing technological advancements through telemedicine will hasten the process of satisfying the requirements of the present and the future. Recent research has contributed to looking at the acceptability, efficacy, practicability, and comparability of virtual consultations to in-person consultations finding positive results with respect to elevated levels of satisfaction for both practitioners and patients (Kalaivanan et al., 2021).

Social connectivity and reduction in isolation

Provided through social networks, social support not only boosts involvement but also helps with symptoms of anxiety and depression. A systematic review found that digital interventions for mental health with social components have been demonstrated to significantly improve mental health outcomes. In fact, one study even evaluated participants who had signed up for a physical activity program and had the option of doing parts of the exercises in a group. People who participated in the group activity encouraged more social engagement, which clearly improved mental health. Due to these results and support from past literature, it can be established that user engagement is facilitated by an intervention's impact on participants' sense of social connectivity, which is, the ability to connect with peers and even maintain frequent communication with a personal therapist (Riadi et al., 2022).

Mental well-being and therapy

Research suggests that digital mental health interventions such as computer-assisted therapy, smartphone apps, and wearable technologies are effective for the treatment, diagnosis, and alleviation of depression and anxiety symptoms among the younger and middle-aged population. It has been determined through past studies that digitally delivered cognitive behavioral therapy can be considered a low-intensity psychological intervention that can aid older adults with mild-to-moderate mental health problems (Riadi et al., 2022).

Proving to be effective at delivering digital therapy, Smartphone apps for mental health that are evidence-based are viewed as the best options. According to one metaanalysis, smartphone therapies that are both directed and unguided can lessen anxiety. Additionally, other research demonstrated that smartphone apps and other digital health interventions significantly reduced clinical symptoms of sadness, anxiety, and psychosis. Even while studies indicate that guided apps are more successful than automated digital interventions, guided apps have the potential to add to the workload of healthcare workers. As such, there seems to be a trade-off between ensuring psychological support and the provision of therapy that is scalable and accessible, whilst balancing staff workloads and availability of face-to-face resources (Tong et al., 2022).

Disease monitoring and management

Wearable technology includes a variety of sensors that support novel techniques for continuous monitoring of biological, behavioral, or environmental data for delivering interventions and evaluating their results for the elderly. Examples of wearable technology include smartphones, smartwatches, and wristbands. Such sensor systems provide highly accurate monitoring of health-related features. The same is enabled by mHealth for tracking and reminding for mental health as well, simple things like mood tracking, sending affirmations as reminders, allowing for accessible consultations and aiding receiving of mental health services for those with less mobility. This technology is particularly ideally suited for delivering digital therapies and for self-evaluation of behavioral characteristics, ultimately allowing precise and novel information on physiological, psychological, emotional, and environmental states to be extracted by creating algorithms using sensor data and additional self-reported data. Utilizing mobile technology also provides fresh approaches to the provision of healthcare services, such as the use of tailored feedback based on the observation of behavior in settings with ecological validity. mHealth offers the potential for population- and individual-level health monitoring and can promote healthy behaviors among the elderly to avert or lessen health issues (Helbostad et al., 2017).

Critical analysis of digital health applications for healthy aging

It is well evidenced that older people especially those in developed countries (where lifestyles are more digitized), are familiar with the digital health technologies for HA (Ienca et al., 2021). An increasing number of older adults are digitally engaging and becoming competent technology users through improved accessibility features, and user-centric and experience-based designs. There has also been a rise in educational skills that equip older adults with essential digital skills. However, there is a long way to close the digital divide between the ages, those between 65 and 79 years tend to use digital devices much more as compared to those 80 years and above (Kebede et al., 2022). A similar trend was reflected in a research survey carried out by Pew Research Center (2017) that revealed that the percentage of smartphone owners in the age group of 80 + years fell to 17% from that of 59% in those between 65 and 69 years. The digital developers' presupposition that *one size does fit all* fails to account for older adult's physical and mental capability, accessibility needs, age-related changes, and lack of skill and support which are plausible reasons to explain the dwindling percentage in users. To note, the data is not representative of the global older adults.

There are various factors that affect older adults' use of digital devices. A scoping review of 96 studies enlists various barriers and facilitators of older users' digital engagement based on some common factors viz., skills and knowledge about the digital devices, physical capability and psychological capability, beliefs about their ability and challenges, optimism about using to use digital devices, intention and goals to use digital devices, emotions attached to digital devices and the role of social influence in the use of digital devices.

There are several advantages and disadvantages associated with digital interventions for the mental health of the elderly (Kebede et al., 2022) and are summarized as follows:

Advantages	Disadvantages
• Quick accessibility of mental health support and services in remote locations • Availability of written guide and knowledge of accessibility futures, e.g., how to adjust font size • Willingness to learn or adopt technology • Higher educational status and history of having used technology at work • Enthusiastic attitude and positive technological experience • Positive health-seeking behavior and ability to monitor health • Independence and a sense of autonomy along with a sense of connection or connectedness and interaction via the internet • Technologies that can be customized to older adults' needs, abilities, and preferences.	• Limited exposure to modern digital technologies and consequent lack of digital literacy and know-how • Lack of training and lack of digital competency and technical skills • Reduced sensory perception or physical (impaired vision, hearing, and dexterity) and cognitive limitations (memory loss and forgetfulness) • Aversion and limited or lack of interest; possible technophobia • Fear of addiction or habit-forming nature especially with internet-based digital technologies • Preference to spend time on family and other valuable activities sometimes may also include dependence on family members or caregivers • Preference for inactive lifestyle in old age (satisfied with current activity performance)

Older people's user experience with digital health applications

The user experience of older people with digital health applications is a topic of growing importance as technology continues to play a significant role in healthcare delivery. Digital health applications, such as mobile apps, wearable devices, and online portals, have the potential to provide various benefits to older individuals, including better access to health information, monitoring of chronic conditions, MM, and communication with healthcare providers. There are several factors that influence the user experience of older adults with these applications. Older adults may face challenges in using digital health applications due to age-related changes in vision, hearing, dexterity, and cognitive abilities. Designing applications with larger fonts, clear icons, intuitive navigation, and compatibility with assistive technologies can enhance their usability and accessibility (Hall et al., 2015). Older users tend to prefer simple and straightforward interfaces. Applications that have a minimal learning curve and offer step-by-step guidance are more likely to be well-received by this demographic. Offering options to customize the user interface, font sizes, color schemes, and notification settings can help older users tailor the application to their preferences and needs.

Older adults may be overwhelmed by excessive amounts of information. Presenting health-related information in a clear and concise manner is crucial to ensure they understand the content and can make informed decisions (Chan & Honey, 2022).

Older users may have concerns about the security and privacy of their health data. Clearly explaining data handling practices and incorporating robust security measures can help alleviate these concerns. Providing easily accessible user support and training resources can help older adults feel more confident in using the application. This might include tutorials, FAQs, and the option for real-time assistance. Involving older adults in the design and testing phases of digital health applications can provide valuable insights into their preferences, needs, and challenges. User feedback loops can lead to continuous improvements (Curtis & Price, 2017).

Digital health applications can also address issues related to social isolation by enabling communication with healthcare providers, family members, and peers. Integrating features that foster connectivity can enhance the overall user experience. Older adults might be using a variety of devices, ranging from smartphones and tablets to desktop computers. Ensuring compatibility across different devices and platforms is essential for broad accessibility. In summary, creating a positive user experience for older individuals with digital health applications requires a user-centered design approach that takes into account their unique needs, preferences, and challenges. By focusing on usability, accessibility, simplicity, security, and customization, developers can create applications that effectively empower older adults to manage their health and well-being using technology (Mace et al., 2022).

The potential role of digital health applications: a comment on integrating ethical and practical concerns

Digital healthcare is a relatively new phenomenon that provides a valuable complement adjunct to physical primary care by reducing costs, improving access to healthcare, and allowing patient monitoring. However, such platforms are mainly and conveniently used today by the younger generations, which creates a "digital divide" between the younger and the elderly. This is truer for developing nations where the rates of digitization are further sparse widening the digital divide (Ienca et al., 2021).

Some common challenges when it comes to elderly using digital healthcare for HA are: digital use is customarily associated with the youth than with the elderly, digital developers often bypass to include supporting features of digital devices for the elderly, the elderly's rate of adoption and usage of digital health tends to be low in comparison to the population average even when the need for health regulation is higher among the elderly, underrepresentation in research to study elderly digital use, and the financial dependence that elderly may have versus the financial independence of the youth that may reduce the access of digital health, among various other factors.

These factors may also be socio-culturally varied and will strongly be determined by the internet penetration, overall mental healthcare burden and status along with the attitudes towards digitization; for example, developing countries may not have adequate resources to support digital mental healthcare as compared to developed nations where digitization is predominant in the public healthcare infrastructure thus making it accessible for mental healthcare as well (Wangmo et al., 2019)

Some common ethical values of digital health and exemplification of the issues involved are as follows (Daniels, 2008; Royakkers et al., 2018):

Ethical values	Exemplification of issues involved
Justice	Equity in access, exclusion, equal treatment, nondiscrimination, nonstigmatization, data ownership, empowerment
Autonomy	Freedom of choice, informed consent, awareness of data collection and use, right to (not) know results
Privacy	Data protection, confidentiality, data sharing, intended/unintended uses of data
Security	Data storage, safety of information, protection against unauthorized access and use of data
Responsibilities	Trust, balance of power, relation between stakeholders (e.g., user—government—provider), benefits and benefit sharing, data ownership
Procedural values	Transparency, accountability, inclusiveness

Irrespective of the omnipresence of digitization of mental healthcare in some parts of the globe, digital mental healthcare access for the elderly is met with several ethical and legal dilemmas. Some of the concerns pertinent to the elderly are discussed briefly as follows:

1. *Lack of access and affordability of digital mental healthcare*: With uneven internet penetration, lack of overall digitization of the healthcare infrastructure and fluctuating affordability, digital mental healthcare for the elderly remains askew at a global level, leaving the benefits of access and affordability to few. In general, the employment of digital health technologies also gives rise to inequalities in access which go beyond the affordability of the technology, and also depend on the individual's technological ability and capacity to engage with digital health tools. When certain populations such as the elderly are excluded from using such technologies, for instance, due to digital illiteracy, the danger of an unjust health system becomes prevalent (Brall et al., 2019).
2. *Lack of transparency, privacy and technical know-how*: In order to make the correct, judicious and rightful use of the benefits of digital mental healthcare, the digitized version of care must come with adequate information for use, provide risks and

benefits and come with culturally relevant and simple to understand instructions for use. Only then, can it be fit for use for all where there may be a gap in digital literacy and know-how. Thus, open communication, technical training and education should be offered to the elderly users, professionals as well as caregivers who may aid the elderly to equip them to judicious use of digital mental healthcare. Under patient rights, users should be aware that their data are being collected for health-related purposes. Challenges of ethical concern arise with regard to storage, access, sharing and ownership of data as well as the return of results. Apart from touching on relevant ethical considerations in line with security, privacy, confidentiality, discrimination, unintended uses of data and right to know or not to know results about sometimes incidental findings, these aspects also have implications for fair use of digital health (Brall et al., 2019).

3. *Dignity of the elderly*: As the dignity of a patient is maintained by a mental health professional in the traditional care setup, it should also be maintained in digital healthcare medium. For instance, communicating sensitive news, disclosing a diagnosis or providing palliative care.

Overall, digital mental healthcare needs the following values to be instated for fair and unanimously beneficial service: (1) human agency and oversight, (2) technical robustness and safety, (3) privacy and data governance, (4) transparency, (5) diversity, nondiscrimination and fairness, (5) societal and environmental well-being, and (6) accountability (European Commission, 2019).

Need for guidelines

The digitalization consequent to COVID-19 led to more widespread use of digital mental health services. This in itself is a research opportunity. There is rapidly accumulating data on the acceptability and effectiveness of these services as a greater number of people are engaging with digital mental health services. Though digital literacy is increasing, older adults might still lack experience with and access to digital tools, preventing them from using technologies effectively. Most mHealth apps are not mindfully designed for older adults, making digital mental health services inaccessible as the elderly have low technical readiness and trust in technologies (Rasche et al., 2018). Although digital technology for older adults might overcome some common barriers to traditionally delivered mental health services, such as cost, stigma and transportation issues, implementations of digital mental health services for older adults should strategically target trust, buy-in and technical skill training or support to maximize the likelihood of success. There is a need for better strategized and greater equitable access to mental healthcare in continued expansions of digital mental health services.

These guidelines are in addition to those that are required to address the routine challenges of confidentiality, privacy and likewise ethical concerns.

Conclusion

Though the history dates back to the 1960s, to reduce the risk of COVID-19 transmission, healthcare professionals quickly made the switch to web-based mental healthcare delivery. Moreover, successful use of digital approaches at scale requires technology support and even that may be insufficient in terms of generating engagement, since digital literacy is a challenge, particularly among older adults from minority backgrounds, with low income, and on Medicare. It is also unclear how increasing rates of clinician burnout being reported over the pandemic may factor into the scaling of digital care, given the need for clinician training and the fact that older adults with cognitive impairment or sensory impairment need even more support from staff and clinicians to successfully navigate technology. The current state of the evidence about the efficacy of digital therapies is ambiguous, and it is challenging to foresee how such a significant change to digital health platforms will affect health outcomes. It is unclear whether clinicians can conduct evaluations, detect illnesses and symptoms, control suicidal tendencies, and offer personable, empathetic care. The symptomatology of various mental health illnesses, coexisting medical conditions, and socioeconomic circumstances may also make digital treatment delivery challenging. Overall, the provision of care and the general health of patients may be adversely affected by a lack of knowledge, resources, and awareness of complicated patient-related aspects. Thus, there is a need for adequate guidelines to address the ethical and practical issues of digital mental health in order to support elderly mental health and ensure that the elderly can engage with digital mental health services with greater ease and access.

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SECTION II

Healthcare systems and healthcare workforce: toward digital transformation

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CHAPTER 5

Opportunities and challenges facing the accounting information system in medical institutions when adopting Internet of Things

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Introduction

With the spread of consumer-centric internet culture, as well as advances in information and communication technologies, companies are starting to think differently about how to create value for consumers. By trying to take advantage of this technological progress to develop customer loyalty (Mwenemeru & Nzuki, 2015). Information and communication technology has great capabilities to operate large amounts of data at high speed, with high accuracy, and at a lower cost, thus businesses can implement their strategy and achieve (Kinney & Raiborn, 2011). The term "Internet of Things" (IoT) was used first time by Kevin Ashton in 1999 (Rashed, 2017). Then the IoT began to spread in all industrial, agricultural, commercial fields, fields of healthcare, transportation, etc. IoT is an emerging technology that reflects the possibility of the caller to deal with things at any time, from anywhere (Samhale, 2022). This technology consists of a network of sensors, and smart devices, along with advanced data analytics and cloud services. This technology has the ability to collect a large amount of data from the environment with the help of sensors, and then send the collected data to servers for processing by smart devices (Mwenemeru & Nzuki, 2015; Samhale, 2022). The main goal of the IoT is to "unify everything in Our world is under a shared infrastructure, which gives us not only control over the things around us, but also informs us about the state of things" (Madakam et al., 2015).

This new technology is ubiquitous in our daily lives, taking advantage of the rapid growth of Internet infrastructure Wi-Fi, 4G and radio frequency identification 2 (RFID2) (Palattella et al., 2012; Samhale, 2022). According to Fortune Business Insights, the global IoT market is expected to grow from \$478.36 billion in 2022 to \$110.6 billion in 2020 and \$2465.26 billion by 2029, at a compound annual growth rate of 26.4% (Rejeb et al.,

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2023a, 2023b). The IoT offers tremendous opportunities in the field of healthcare, as it plays a crucial role in all healthcare facilities, even in patients' homes (Rejeb et al., 2023a, 2023b). In addition, it makes it possible to provide a "one-stop" service to residents in remote locations (Yuehong et al., 2016). In contrast to traditional health services at the site of local hospitals, IoT can share all resources related to patients to provide them with flexible and convenient treatment. The deployment of IoT in remote health monitoring also has tremendous potential to improve the quality of healthcare services and reduce costs through early detection and prevention of diseases and other potentially serious conditions. Medical institutions have benefited from the "IoT" technology. The IoT in Health has revolutionized clinical research and disease treatments. Now, the data is recorded and transmitted via the Internet, and the patterns of heart rate, pulse, temperature, blood pressure, body sugar level, and digestive system are monitored. Which helps doctors to make a quick and accurate diagnosis (Almotiri et al., 2016). In addition, smart devices that rely on IoT technology provide many possibilities for applications such as online monitoring, monitoring of fitness programs, diseases, taking medications, and caring for the elderly. The IoT also allows the integration of medical devices and the possibility of exchanging data between them. Aceto et al. (2020) and Samhale (2022) found that the use of IoT in Italian hospitals led to an improvement in the service performance of patients and increased their satisfaction with the performance of the health system. The IoT can be used in the field of healthcare by monitoring and studying the activity of individuals and patients through mobile devices such as smartphones contributing to a more accurate diagnosis of health conditions, and the possibility of sending information to the doctor for analysis and taking the appropriate medical action. These connected devices take vital data in the body throughout the day to be transmitted wirelessly to the doctor's devices such as computers and smartphones, in addition to enhancing patients' participation and interaction with doctors, which contributes to reducing medical expenses (Abdulshahed et al., 2019). According to Fortune Business Insights, the medical IoT market is growing rapidly, as it is expected that the value of this market will reach $187.6 billion by 2028, up from only $41 billion in 2020, with an annual growth rate of 29.5%. The accounting information system (AIS) is a general framework that includes a group of interrelated elements that interact with each other within a specific framework in order to collect, record, summarize, save and report financial and nonfinancial events according to a set of rules and procedures with the aim of providing information about the current situation, information to direct attention and information that helps in making decisions, for users inside and outside the institutions. AIS consists of subinformation systems which are the financial AIS, the management AIS, and the cost information system.

The IoT can be used in medical institutions in particular as a System Gathering Data collection system where data is collected from sensors. The use of IoT devices allows the possibility of diagnosing and monitoring the health of patients and recording and transmitting data via the Internet. The IoT can also be used as a System

Alert—Monitoring system, where data is collected from sensors and analyzed, and alerts are issued when certain criteria are reached, such as monitoring the patient's health status. The IoT can also be used as a System Analysis, where data is collected from Sensors and their analysis, but in this case, the analysis is continuous, so that reports are generated periodically every (hour—day) such as preparing a report every hour or day about the patient's health status in light of the data we get from the sensors in addition to the above The IoT can be used as a system control where sensor data analysis leads to remote actuators. Such as controlling lighting — temperature (Serpanos & Wolf, 2017, p. 3). A study (Rejeb, et al, 2023a), which examined 2990 articles published in academic journals, showed that applications of the IoT, blockchain, artificial intelligence, 5G, as well as big data analytics are widely applied in healthcare institutions. In addition, Yuehong et al. (2016) examined IoT applications in healthcare from the perspective of enabling technologies and methodologies and found that IoT is widely applied in healthcare. Therefore, information systems will be the largest affected by the IoT, and there has been a need for an AIS in facilities in medical institutions. In particular, it depends on the IoT technology and integrates with data-based strategies, in order to obtain information continuously in real-time (instantaneous information), which represents the key to success for companies, which helps them achieve their goals and strategies.

The main contribution of this study is that it is the first of its kind which deals with the opportunities and threats facing the AIS in hospitals when using the IoT, as well as showing how the AIS can benefit from the opportunities offered by IoT in hospitals, and at the same time showing how to face the risks of adopting IoT technology on the AIS in hospitals. The research question that inspired this study was as follows:

What are the threats facing the AIS in hospitals when adopting IoT technology? From this question, the following subquestions:

1. What are the opportunities created by using the IoT for the AIS?
2. What are the threats and challenges resulting from the use of the IoT for the AIS?
3. How to face the risks of adopting IoT technology on the AIS in hospitals?

In order to achieve the objectives of the research, the second section will deal with previous studies, the third section will be devoted to the opportunities offered by the use of the IoT for the accounting system, while the fourth section will deal with the threats and challenges facing the accounting system resulting from the use of the IoT in hospitals, and the last section has been devoted to a summary Research and recommendations

Previous studies

Many articles have addressed the impact of modern technologies (IoT, blockchain, artificial intelligence (AI), 5G, and big data analytics) on healthcare in various countries of the world, including Asian countries and the Arab Gulf countries. Maksimović and

Vujović (2017) examined the impact of e-health systems based on the IoT on healthcare. The study argues that e-health solutions based on the IoT are expected to revolutionize the healthcare industry. The study concluded that the rapid growth of the IoT, in addition to the wide spread of new technologies and sensors, has led to the emergence of new opportunities for the way to treat patients, which contributes to improving human health, providing high-quality healthcare and cost-effective of healthcare. Marques et al. (2019) examined IoT architectures for enhanced living environments and healthcare systems, with a focus on challenges and opportunities, core operating systems, and open-source operating systems. The study concluded that open-source solutions improve the efficiency of healthcare systems by enabling devices, applications, and systems to securely expose APIs to external systems. This will improve interoperability and reduce the cost of device network management and governance. A study by Mongelli et al. (2020) dealt with the design of a technological platform for remote monitoring of patients with chronic obstructive pulmonary disease. The proposed system can support a new model for managing patients with the disease, by integrating the daily clinical data of the patient and providing the doctor with a picture of the impact of the disease on the lifestyle that is monitored using artificial intelligence algorithms. Kelly et al. (2020) attempted to provide an overview of current IoT technology in healthcare, and identify how IoT devices improve healthcare services. In addition to identifying the problems and obstacles facing the application of the IoT in healthcare. The study found that modern technological developments provide a great opportunity for healthcare systems to proactively predict health problems, in addition to diagnosing and treating diseases inside and outside the hospital. However, implementing IoT in healthcare will depend on clear and robust codes of practice for data management. Additionally, there are still important IoT gaps that future research needs to address. Bhuiyan et al. (2021) dealt with developments in healthcare methods based on the IoT. IoT protocols for healthcare are analyzed with a broad discussion presented. The study proposed a security architecture model based on the IoT to mitigate security problems. A study by Bhuiyan et al. (2022) analyzed different health monitoring systems based on the IoT and the challenges they face. The study searched journal and conference databases using specific keywords to find scholarly works on the topic. Yacob et al. (2020) aimed to provide an overview of the IoT, by reviewing the relevant literature, describing the applications, and the challenges facing the application of the IoT. The study found that the IoT is applied in many fields including medicine, healthcare, education, communications, industry, construction, and agriculture. Sriborrirux and Laortum (2020) proposed an IoT edge gateway framework based on docker container technology to enable microservices architectures to help monitor sites of nursing homes and residential care centers. The framework is used to identify IoT devices and the gateway itself in home networks to allow only authorized persons to access the devices. The study also suggested the use of the latest hardware-based security methods that support the mutual authentication process using the digital signature algorithm to verify the authenticity of the device, the gateway, and the integrity of the cloud platform, and to detect any unauthorized manipulation or penetration of data (Kong et al., 2022). Try to explore new ways to create value in the medical field. The study classified (IoT) technologies into four categories according to the information collected (location, environmental criteria, energy consumption, and biometrics). The study found that the IoT contributes to accurately diagnosing diseases and providing appropriate and effective treatment. In addition, measuring environmental parameters plays an important role in identifying environmental factors that are harmful to patients. Moreover, the use of energy metering technology allows for increased energy efficiency. Finally, all of these factors contribute to improving the cost-effectiveness of hospitals. Bhatt and Chakraborty (2023) examined the relationship between IoT adoption and its impact on patient care service engagement. The results of the study showed that adopting a wearable IoT device in healthcare opens new opportunities in healthcare delivery and disrupts the traditional method, by enabling the patient to participate in decision-making.

Opportunities of the Internet of Things for the accounting system in medical institutions

Technological progress plays a major role in bringing about economic growth in the era of globalization. The proper choice of information technology will positively affect the efficiency of the establishments and their ability to survive, grow, and continue to provide their services to the public in an appropriate manner.

IoT has become a commodity. A new, profitable and fast-growing industry was born, so some investors now describe it as a commodity that will resemble oil in its value and importance for investment, and it is a mixture of processes and tools related to the use and management of a huge amount of data collected from many sources and through many platforms. IoT is the collection and interpretation of huge data sets, made possible by vast computing power that monitors a variety of digital flows — such as sensors, market interactions, and social information exchange — and analyzes them using "intelligent" algorithms. It presents a promising new way to explore new opportunities to deliver high-value products and services to customers (Davenport, 2014). Big data is related to the IoT, as this phenomenon depends on the interaction of factors that lead to the production of huge amounts of information from different sources, which are potentially generated by everything and everywhere. Valentinetti and Muñoz (2021) argue that the accounting profession is facing extinction, there is an opportunity for accountants and the ability to create value in the world of big data analytics. Accountants already excel at problem-based analysis of structured data, well positioned to take a leadership role in analysis-based their argument is based on the fact that accountants are familiar with structured data sets, ease the transition to working with unstructured data, and possess knowledge of business fundamentals. Thus, rather than replacing accountants, we see Big data analytics complements accountants' skills and knowledge. It can be said that the use of the IoT will be positively affected by providing multiple opportunities for the development of financial AIS and management of AISs and costs. These opportunities can be highlighted in the following:

1. Data entry under the use of the IoT will be characterized by Immediacy via wired and wireless networks (Bluetooth, RFID, GPS, and cloud computing) since the sensors can capture data continuously and thus there will be a minimum of errors resulting from data entry through the human element (Cao & Zhu, 2012; Chang et al., 2020; O'Leary, 2013). In addition to that, we provide the IoT to the accounting system with real-time predictive ability (sensors that can monitor the use of items). Thus, IoT will benefit the accounting system by supplying data as soon as it occurs and will help minimize data entry errors as well as reduce time in data management and efforts to distribute information, as data can be automated and analyzed, making medical institutions more flexible and efficient. This data analysis process will enable medical organizations to optimize resource allocation.
2. The IoT helps to improve the characteristics of the quality of accounting information resulting from the accounting system. The data and information generated from the IoT are characterized by speed, appropriateness, transparency, and accuracy, and serve the decision-maker in a timely manner, in addition to the unprecedented use of predictive information technologies in real-time (sensors that can monitor usage items). In addition to that, improving the comparability feature, as the IoT helps to prepare various analytical reports for comparison purposes (Hamilton, 2021; Watson, 2023).
3. The IoT is available to the management AIS, data that helps in evaluating performance using financial and nonfinancial indicators. This is due to the fact that only financial performance in hospitals may not accurately reflect the extent of efficiency and is related to the quality of the service provided, and given that they are heterogeneous services, performance evaluation in hospitals should be subject to several metrics. In addition, the IoT helps the accounting system provide information on performance measures that represent performance drivers and performance measures that represent outcome measures. The interrelationship between performance measures indicates that the use of results measures only without performance causes will result in not providing information on how to achieve results, and at the same time using performance causes without results measures may lead to improving operations in the short-term, but it may fail to reveal whether these the improvements in the operational processes have resulted in effects in the form of tangible financial results, then it can be said that the IoT helps in applying the latest methods of evaluating and measuring performance in institutions. The IoT generates a

wide range of data that gives new opportunities to identify behaviors associated with the results of goals and the ability to formulate, store, and analyze performance measures.

4. The IoT can be used to process patients' financial information. It has the ability to save the data of a large number of patients and to save a huge amount of their data, in addition to the high speed and accuracy in data processing. IoT networks can also help report any accounting problems related to patients, which helps maintain the integrity of accounting information (Hamilton, 2021). Moreover, the IoT, when integrated with blockchains, helps verify the identity of the patient and the doctor in an automatic manner, which gives a guarantee of information security when agreeing between the contracting parties via electronic networks.
5. The IoT helps in solving the problem of indexing patient records. One of the common problems in healthcare data in many countries is issues of duplication of information or mismatch of patient files due to entering patient data and information in different ways. The IoT helps in solving such problems, as well as the IoT helps in adding different data to patient files received from technical devices that measure various health indicators, and healthcare service providers benefit from collecting this information in devising the best ways to provide the necessary care for patients (Mahmoud, 2022)
6. The IoT helps tracking of medicines for each case, to prevent the arrival of unsafe medicines to patients who may not be aware of them. In addition, checking the expiration date of medicines and drug supply contracts. The IoT helps users to obtain and exchange information with great speed and high accuracy (Cao & Zhu, 2012). The IoT is one of the emerging technologies that can achieve linkage between the company and the stakeholders and between the company and other related companies, as it relies on three basic insights: "things-oriented and semantic-oriented" and "internet-oriented" (Lu et al. 2018). However, adopting the IoT also leads to raising the level of trust in medical institutions by building bridges of cooperation, enhancing mutual trust between health institutions and stakeholders, increasing transparency, electronic community participation, and providing useful data to beneficiaries.
7. Provide accurate information on the costs of health services. The services provided by hospitals to their patients are heterogeneous and atypical services and depend on the patient's condition and the necessary treatment, and then each patient differs from the other, which requires calculating the cost of each patient independently. Under the IoT costs can be reduced in several ways. In some cases, patients can be assigned wearable devices for remote monitoring, this enables hospitals to reduce costs by allowing patients to leave the hospital early when home observation is a viable alternative. Increased use of such devices in patient care will reduce healthcare costs and improve healthcare outcomes. The cost accounting system with the

help of the IoT data provides the possibility of determining the costs of each patient quickly and with high accuracy. Thus, the costs of health services can be appropriately calculated. In addition, the data provided by the IoT helps health organizations implement modern costing systems such as resource consumption accounting, activity-based costing, and time-driven activity-based costing.

8. The IoT helps to build new models that help simplify procedures and reduce service time, and thus reduce costs, by excluding activities that do not add value to the patient. In addition, the adoption of IoT technology can help analyze costs by tracking sensors for the original path of the product and automatically recording any deviations from the correct track. Moreover, The IoT can also help reduce energy costs through the use of sensors to measure the actual use of energy by machines (Rabai, 2022).
9. Facilitate audits and increase the effectiveness of control procedures aimed at preserving the assets and resources of medical institutions. With the help of the IoT, all transactions can be tracked and sent to the accounting department in real-time. Hence, if you make a donation, complete a purchase, or receive an amount of money, the accountants already know it. Using the IoT also simplifies the accounting process to the point where the efforts for auditing are greatly reduced. This also leads to an error-free checkout process. Thus, the IoT provides reliable information about assets and how to exploit and maintain them. The internal control to protect the various assets.

Challenges facing the accounting information system with the use of the Internet of Things in medical institutions

The business landscape continues to change and evolve with increasing speed. The data that is collected from reality may not be of much help in making decisions, as it is characterized by generality and detail and does not explain the relationships between things, people, events and processes in a specific and useful way. Thus, the data needs operational processes in order to convert it into useful information for the decision-maker (Magor, 2017). The creation and transfer of data in the IoT environment leads to the exposure of this data and information to risk by attackers as a result of the transmission of data and information over networks (Saif et al., 2015). The National Institute of Standards and Technology found that there are three considerations that may affect the management of cybersecurity and risks for IoT devices, compared to traditional information technology devices. These considerations are as follows (Boeckl et al., 2019):

1. Many IoT devices interact with the physical world in ways that traditional IT devices do not interact with.

2. Many IoT devices cannot be accessed, managed, or monitored in the same ways as traditional IT devices.
3. The efficiency and effectiveness of the cybersecurity and privacy capabilities of IoT devices differ from traditional IT devices

In addition, Chang et al. (2020) believe that the threats and risks related to the IoT are different than ever before, and that information and network security management in the IoT environment is still in its infancy. At the same time, the 2013 AChartered Global Management Accountant report, "From Insight to Impact — Unlocking Opportunities in Big Data," reveals three relevant findings (Rezaee & Wang, 2017):

- 86% of professionals surveyed agree that "their business struggles to extract valuable information from data."
- Professional accountants in companies must change from proponents of decision-making to business partners, in order to create value for companies and establish an evidence-based base. A decision-making culture is more than a culture based on management opinions.
- Management accountants should learn more about information security and the Internet.

It is known that the IoT presents great opportunities for the development of the AIS, but these opportunities are accompanied by many challenges represented in security and privacy, the need for complex and unconventional tools and programs for data analysis, in addition to human skills and experiences to provide useful information for the decision-maker. Among the most important challenges facing the accounting system when applying the IoT are as follows:

1. Security and privacy: While security considerations within the context of information technology are nothing new, the features of many IoT applications will pose new and unique security challenges. Manufacturers typically face technical and economic challenges when building and maintaining IoT devices with robust and effective security features. However, weakly secured devices and services will be vulnerable to cyberattacks, which may lead to user data being exposed and stolen creating potential entry points for hackers and leaving sensitive information vulnerable, and vulnerable (Chang et al., 2020; Martens et al., 2022). Therefore, security and privacy are considered the main challenges for IoT technology due to the increasing number of connected devices, which increases the possibility of security vulnerabilities that can be exploited. Which requires the design of a safe physical system and the design of a safe cloud computing system. The issue of security in the IoT refers to data confidentiality, meaning the protection of data and information from access by parties who do not have the right to access it (Yacob et al., 2020, p. 376). Although cloud service providers use some security mechanisms to ensure data security, in some cases, data leakage may occur. Also, cloud service providers pledge the security of data, but there is no legal responsibility on them

regarding the potential threat to the security of this data (Murthy et al., 2020, p. 205192). In the health aspect, patient safety is the top priority. However, most IoT devices that are used to transmit health data in real-time are vulnerable to cybercriminals who can compromise systems to steal health information. Therefore, ensuring the security of IoT products and services must be a primary priority to maintain user confidence in this technology.

2. Data quality and storage: A single healthcare organization with many devices generates massive amounts of health data. Storage needs for IoT in healthcare are expected to increase exponentially, from terabytes to petabytes. However, despite the unique technological characteristics of IoT technology, its broad fields of application, multiple levels of implementation, the advantages it provides, and the huge amounts of data it produces, it faces various challenges, the most important of which is the limited computing and storage capabilities of sensors that collect data in real-time (Humayun 2020). Therefore, organizations must adopt new data management models and employ them well to serve decision-making processes (Hassani et al., 2019) which facilitates access to information from anywhere, at any time and from any device (Weng, 2020; Yacob et al., 2020).
3. Human resources skills: The human resource is a critical point in the efficiency of applying modern technological systems. When human resources are aware of technology and information security policies and procedures, they are more efficient in managing IoT and information security implementation tasks. SAS (2015) explained that the lack of competencies and capabilities within the accounting system capable of leading digital transformation programs towards effective use is a major challenge facing the application of the IoT in accounting. All IoT challenges can be controlled and addressed when organizations have a team of highly skilled programmers, technicians, and accountants trained in IoT implementation. Often, the problem facing the accounting system is the lack of staff and the insufficient training procedures. Accountants (especially management accountants) are increasingly relying on technology to improve the efficiency and effectiveness of the AIS. Therefore, the organization will need accountants with more diverse talents and competencies, and accountants are expected to understand the links between business operations and the risks associated with them and to develop innovative ways to assess risks. It is also necessary to create a culture of awareness of the importance of cybersecurity for the AIS, and for accountants to understand the nature of the IoT and the risks that it can generate (Lee, 2020). Therefore, accountants must play an effective role in protecting information and privacy, which enables them to anticipate and discover any risks, events, behaviors or situations related to privacy. In addition, accountants must provide managers with information that helps them obtain a clear view of employees, suppliers, customers, and stakeholders in the privacy of the company and identify the risks resulting from the use of the IoT

(Rabai, 2022). In addition, accountants with experience and skills can be involved in protecting accounting data and systems oversight (Zadorozhnyi et al., 2020).

4. Internal policy: Company policy affects data shared internally, both between and within departments, as well as how data is shared with third parties (Schroeder, 2016). Companies need to implement a set of controls to protect unauthorized company information. It also requires a strong governance system to manage risks, by defining the data that must be protected, developing guidelines on how to securely collect, use and store data and prevent unwanted breaches. In addition to determining who has access to information in the accounting system and identifying those responsible in the event of a breach of data or the company's information system (Saif et al., 2015).
5. IoT devices: The huge size of the IoT, with many devices relying on it, represents one of the important challenges facing the accounting system. A single failure of any software or hardware can have consequences for the functioning of the entire system. To confront such cases, some techniques can be used to ensure the confidentiality of information, or techniques that detect and address threats and vulnerabilities in the system can be used. In addition, it is necessary to develop a set of technology controls that help the AIS face the risks of adopting the IoT (Lee, 2020; Rabai, 2022).
6. Integration and compatibility of IoT devices: Compatibility between various IoT devices, whether new or old, is one of the most important problems facing the AIS. This is because medical device companies fail to achieve seamless integration between IoT-enabled devices since there is no concurrent protocol to follow to collect data. The reason for this is that device manufacturers have not reached a consensus on communication protocol and standards. In medical institutions, devices such as drug delivery systems, heart monitors, thermometers, etc. are connected to devices and sensors, there are many languages, standards, and protocols used. This requires the management accountant to collect information about the used IoT devices that the company wants to purchase to ensure compatibility between the devices because this works to ensure that its programs and devices are operable, and to reduce the cost of data collection and keeping the system secure.
7. Cost: Before adopting any new system, the costs involved in designing and operating the system must be compared with the expected benefits. With regard to the use of the IoT, there are various costs associated with the use of the IoT, such as software and hardware costs (the IoT needs devices with special specifications in order to carry out the necessary tasks, which are devices with high costs), costs of training and developing the skills of human resources to work on the IoT. Moreover, there can be early obsolescence problems for IoT devices, which incurs additional costs. Therefore, accountants must consider the costs and benefits of

adopting the IoT such as saving time and manpower for health institutions, improving clinical operations, generating more revenue streams, increasing patient retention, etc., before deciding to use the IoT.

Conclusion

The IoT has greatly contributed to expanding the options for human interaction with the outside world, using advanced protocols and algorithms. In addition, the technologies provided by the IoT have helped healthcare services develop very rapidly. The IoT helps patients to be more involved, have more control over their healthcare, and deepen their understanding of their evolving needs. The IoT can help bridge the shortage in access to medical services in countries and societies where it is difficult for patients to reach hospitals and medical service centers. Since IoT devices are connected to big data, advancing a large pool of data and eliminating the need for raw data collection. Valentinetti and Muñoz (2021) believe that the IoT benefits the accounting system by providing it with data as it occurs, which helps the system manage assets, manage inventory, and improve the quality of data and information. In addition to improving planning processes, continuous monitoring of accounting data, preparing estimated balances, improving risk management, efficient use of resources, etc. The main contribution of this study is that it is the first of its kind that deals with the opportunities and threats facing the AIS in hospitals when using the IoT, as well as showing how the AIS takes advantage of the opportunities offered by the use of the IoT in hospitals, and at the same time showing the risks of adopting this technology on the AIS in hospitals.

The use of the IoT will have a positive impact by providing multiple opportunities to develop the financial AIS and management accounting, including data entry as it occurs, minimizing data entry errors, automating data and analyzing it, improving the characteristics of the quality of accounting information resulting from the accounting system, especially relevance, reliability, and timeliness. Predictive value and comparability, in addition to providing data that helps in evaluating performance using financial and nonfinancial indicators. Although the IoT offers great opportunities, there are many challenges facing the application of the IoT such as security gaps, and risks of privacy violations, in addition to the challenges of unstructured big data that needs to be stored, processed, analyzed, and interpreted. Despite the many benefits of the IoT, there are still many challenges and limitations to its use. The most prominent of which are security and privacy, hardware and software, skills related to the IoT, regulation, legislation and laws.

The limitations of this research are represented in an attempt to highlight the opportunities and threats facing the accounting system in light of the use of the IoT in medical institutions by examining the previous literature. Therefore, it is recommended to conduct future studies that use other research tools such as personal interviews, questionnaires, and applied studies. As well as conducting studies on the expected auditing services for institutions that apply the IoT, in addition to examining the role of the management accountant in decisions to use the IoT, examining the possibility of applying open cost accounting systems in medical institutions that apply the IoT, in addition to examining the impact of using the IoT in health institutions.

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CHAPTER 6

The future of digital health in the era of space internet

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Introduction

The paradigm of space internet, commonly denoted as satellite internet, orchestrates a transformative shift in global connectivity through an orbiting constellation of satellites facilitating widespread internet access (Furqan & Goswami, 2022). These satellites operate as relays, transmitting signals from ground stations to user terminals, ensuring high-speed data dissemination across the globe (Giuliari et al., 2020). This innovation has garnered substantial attention, given its potential to alleviate the digital divide and furnish internet connectivity to remote and underserved regions. Additionally, it proffers advantages in terms of reliability, scalability, and security, thereby addressing challenges inherent in conventional terrestrial networks (Shaengchart & Kraiwanit, 2023a,2023b).

The forthcoming landscape of digital health stands at the precipice of a profound transformation catalyzed by the integration of space internet technology. Fueled by constellations of low Earth orbit (LEO) satellites, the space internet holds the promise of revolutionizing the delivery and accessibility of healthcare, extending its impact beyond terrestrial boundaries to the far reaches of outer space. This synergy between digital health and space internet is poised to redefine healthcare dynamics in myriad ways. The expansive coverage and capabilities are intrinsic to space internet networks are anticipated to dismantle geographical barriers, augment telemedicine, facilitate real-time health monitoring, and bolster endeavors in space exploration. As the trajectory of space internet technology unfolds, the amalgamation of digital health and the cosmic frontier is set to assume a pivotal role in advancing the health and well-being of individuals both on Earth and in outer space (Dietrich et al., 2018).

This chapter elucidates the prospective trajectory of digital health within the paradigm of space internet.

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Connecting the world: the resurgence of low Earth orbit satellite constellations and global internet access

Recent years have witnessed a resurgence of interest in LEO satellite constellations for space internet technology, with notable initiatives led by companies such as SpaceX, OneWeb, and Amazon's Project Kuiper. These endeavors involve deploying expansive constellations comprising small satellites, heralding a transformative era in global high-speed internet access (Cakaj, 2021).

SpaceX's Starlink initiative, a pioneering force in this domain, utilizes a constellation of LEO satellites to deliver high-speed, low-latency internet connectivity globally. This innovative approach minimizes signal latency and amplifies bandwidth compared to traditional geostationary satellite systems (Yadav et al., 2022). Starlink's architecture not only holds the potential to bridge the digital divide but also to connect remote and underserved regions, significantly improving global internet accessibility (Shaengchart & Kraiwanit, 2023a,2023b).

The scalability and adaptability of Starlink make it a valuable asset for diverse applications, including emergency communication, disaster relief, and military use (Cao et al., 2020). Within the digital health landscape, the integration of SpaceX's Starlink technology marks a paradigm shift, offering a promising solution to address long-standing connectivity challenges faced by remote healthcare facilities. The reliable and high-speed internet access provided by Starlink has the capacity to substantially enhance the efficiency of healthcare delivery in underserved areas.

Telemedicine, a cornerstone of digital health, stands to gain significantly from Starlink's capabilities, facilitating seamless telemedicine consultations and improving the accessibility of medical expertise in geographically isolated regions. The swift transmission of medical data supported by Starlink enhances diagnostic accuracy and enables timely treatment decisions. Furthermore, Starlink's connectivity enhances remote patient monitoring, allowing for continuous healthcare oversight and the effective management of chronic diseases. Applications such as telesurgery, tele-education, and knowledge dissemination within the medical field also find robust support in Starlink's low-latency and reliable infrastructure (Nahm et al., 2023).

The convergence of space internet, exemplified by SpaceX's Starlink, and digital health constitutes a transformative and promising frontier in healthcare. The integration of this technology holds the potential to revolutionize healthcare delivery globally. As Starlink and similar technologies continue to advance and achieve broader adoption, they are anticipated to catalyze a fundamental shift in how healthcare is provided, accessed, and practiced on a global scale (Table 6.1).

Table 6.1 Comparison between space internet (SpaceX's Starlink) and cable internet.

Feature	Space internet (Starlink)	Cable internet
Deployment method	LEO satellite constellation	Underground cables
Latency	Low-latency	Varies
Coverage	Global, including remote areas	Typically urban areas
Bandwidth	High-speed, scalable	Varies by location
Connectivity for Remote Areas	Yes	Limited
Use in Emergency Situations	Suitable (e.g., disaster relief)	Dependence on infrastructure
Integration in Digital Health	Promising (telemedicine, remote patient monitoring)	Traditional healthcare infrastructure
Potential applications	Telemedicine, telesurgery, remote education	General internet use
Scalability	Highly scalable	Limited by infrastructure
Impact on Healthcare	Revolutionizes healthcare delivery	Conventional healthcare delivery
Future prospects	Anticipated to transform global healthcare	Evolving technology landscape

Space internet: bridging the healthcare gap in remote and underserved regions

The confluence of healthcare and space technology, notably manifested in the deployment of space internet, emerges as a transformative remedy for the enduring challenges in healthcare delivery within remote and underserved regions. Confronted by the impediments of geographical isolation, infrastructure constraints, and financial limitations, millions worldwide grapple with inadequate access to quality healthcare services. The application of space internet technology, exemplified by initiatives like SpaceX's Starlink, holds significant potential to mitigate this healthcare gap (Bruzelius et al., 2019).

In regions characterized by limited healthcare facilities and a dearth of trained medical professionals, space internet technology presents a breakthrough solution. Initiatives deploying satellite constellations in LEO offer high-speed internet connectivity to the remotest corners of the globe. The introduction of space internet in these areas facilitates telemedicine services, enabling patients to consult healthcare providers remotely. Distinguished by low latency and dependable connectivity, this technology supports real-time video consultations, overcoming traditional geographical barriers that hinder healthcare access (Froehlich et al., 2021).

The advantages of the space internet extend prominently to addressing emergency healthcare needs in remote locales. In critical medical situations, swift access to healthcare expertise becomes pivotal. High-speed internet provision through satellite networks ensures timely assistance from healthcare professionals during emergencies. Real-time transmission of medical data, images, and videos enhances medical decision-making, substantially improving patient outcomes, particularly in regions lacking immediate access to specialized medical care (Wang et al., 2023).

Beyond emergency care, preventive healthcare and disease management also benefit from space internet technology. Chronic patients in remote areas receive continuous health monitoring through wearable devices and telemonitoring solutions. Transmitting vital health data to healthcare providers facilitates early issue detection and timely interventions. Digital health applications deployed via the space internet contribute to remote patient education, medication management, and lifestyle coaching, fostering healthier living in underserved communities.

The availability of high-speed internet empowers remote healthcare facilities with access to current medical information, research, and best practices. Tele-education and training programs elevate the knowledge and skills of local healthcare providers, ensuring continuous professional development. This sustained medical education contributes to the enhancement of healthcare standards in remote regions (Graves et al., 2021).

In sum, space internet technology stands as a pioneering solution to mitigate healthcare disparities in remote and underserved areas. The provision of high-speed, reliable internet connectivity not only facilitates telemedicine but also supports emergency care, disease management, healthcare education, and the overall enhancement of healthcare standards. As this technology evolves, it holds the potential to bridge existing healthcare disparities, rendering quality healthcare universally accessible and ultimately improving the well-being and health of underserved populations (Table 6.2).

Table 6.2 Space internet for healthcare in remote and underserved areas.

Technology exemplified	– SpaceX's Starlink – OneWeb – Amazon's Project Kuiper
Key benefits	– Facilitates telemedicine services – Enables emergency healthcare access – Supports disease management and prevention – Empowers healthcare education and training
Access	– Supports disease management and prevention – Empowers healthcare education and training
Connectivity features	– High-speed – Low-latency – Dependable
Applications	– Telemedicine – Emergency healthcare – Disease management – Telemonitoring – Healthcare education
Improvements achieved	– Overcoming geographical barriers – Real-time medical data transmission – Continuous health monitoring – Knowledge and skill enhancement

Revolutionizing remote surgery: space internet and digital healthcare integration

Surgery in remote and underserved areas poses a substantial healthcare challenge, given the limited access to specialized surgical expertise and resources. The integration of the space internet and digital healthcare technologies emerges as a potential solution to address these challenges and significantly elevate surgical services in such regions. The synergy of high-speed internet connectivity from space-based satellites and telemedicine platforms has the capacity to revolutionize the delivery of surgical care in remote areas (Takács et al., 2016).

This innovative approach facilitates real-time telemedicine consultations and remote surgical guidance, empowering local healthcare providers to collaborate with expert surgeons situated at a distance. Utilizing advanced telehealth solutions, high-quality video conferencing, and remote monitoring, surgical procedures can be supervised, guided, and even remotely assisted by experienced surgeons, thereby enhancing the safety and effectiveness of interventions (Huang et al., 2019).

The ramifications of integrating the space internet and digital healthcare for remote surgery are manifold. First, it enables remote and underprivileged regions to access specialized medical knowledge and expertise from distant healthcare professionals, thereby mitigating healthcare disparities. This access to specialized surgical guidance holds the potential for improved patient outcomes, reduced complications, and life-saving interventions. Second, the capability to conduct remote surgical consultations and guidance empowers local healthcare providers to perform surgical procedures with the support and expertise of remote specialists. This not only minimizes the need for patients to travel long distances for surgical care but also alleviates the strain on healthcare infrastructure and resources, particularly in emergencies requiring immediate surgical intervention. By streamlining patient travel and optimizing resource utilization, space internet and digital healthcare enhance the efficiency and accessibility of surgical services.

Moreover, telemedicine and space internet have the potential to facilitate postoperative care and follow-up, addressing a commonly overlooked aspect in remote settings due to the scarcity of healthcare providers and resources. Remote monitoring, teleconsultations, and secure digital platforms for exchanging medical data enable timely and comprehensive postoperative care, reducing the risks of complications and ensuring better patient recovery (Irarrázaval et al., 2021).

Despite the transformative potential of space internet and digital healthcare, several challenges must be addressed for their successful application in remote surgical contexts. Key issues include the need for robust and reliable internet connectivity in remote areas, technological infrastructure, and the digital literacy of healthcare providers and patients.

In conclusion, the integration of space internet and digital healthcare stands poised to usher in a transformative shift in remote surgery. Through real-time telemedicine consultations, remote surgical guidance, and postoperative care, these technologies offer a means to extend specialized surgical services to underserved areas, diminish the necessity for patient travel, and enhance the overall quality of care. However, addressing connectivity and infrastructure challenges, along with ensuring digital literacy among healthcare providers and patients, is imperative for the successful application of these technologies (Table 6.3).

Table 6.3 Space internet for surgery in remote areas.

Challenge addressed	Remote surgery and limited access to specialized expertise
Key technology	– Space internet – Digital healthcare
Key benefits	– Real-time telemedicine consultations – Remote surgical guidance – Improved patient outcomes and reduced complications – Access to specialized surgical expertise – Enhanced postoperative care
Connectivity features	– High-speed internet connectivity – Telehealth solutions
Applications	– Remote surgery – Collaboration with remote surgeons – Postoperative care
Improvements achieved	– Minimized patient travel – Enhanced healthcare efficiency – Improved quality of care
Challenges	– Robust internet connectivity in remote areas – Technological infrastructure – Digital literacy
Future potential	– Transformation of remote surgery – Better quality of care – Mitigation of healthcare disparities

Space internet as a new frontier in real-time monitoring and prevention

The amalgamation of space internet technology with healthcare has inaugurated a transformative epoch for global healthcare systems, particularly in the realms of monitoring and prevention. The advent of space internet facilitates unparalleled real-time health monitoring and data collection, presenting an array of opportunities to elevate patient monitoring, disease prevention, and health management on a global scale.

Real-time health monitoring, a fundamental tenet of healthcare delivery, gains unprecedented momentum with the availability of high-speed, low-latency internet connectivity through space-based satellites. Wearable devices and sensors, transmitting health data instantaneously, empower healthcare providers to closely monitor vital signs, physiological parameters, and other health indicators. This real-time data transfer facilitates early detection of health issues and timely interventions. The resulting wealth of health data can be leveraged to discern patterns, trends, and potential health risks, enabling proactive preventive and diagnostic measures (Kim et al., 2019).

The convergence of the space internet and healthcare extends the frontiers of remote patient monitoring, benefiting individuals with chronic conditions requiring continuous oversight. Wearable devices can track and transmit real-time data on chronic conditions, fostering proactive self-care and adherence to treatment plans. This approach not only ensures healthcare providers are alerted to deviations from normal health parameters but also empowers patients with the agency over their health, contributing to the prevention of complications and hospitalizations (Gao et al., 2020).

The integration of the space internet technology opens novel avenues for the prevention of infectious diseases, especially pertinent in an era marked by global health crises. Swift sharing of epidemiological data, tele-epidemiology, and rapid response to infectious disease outbreaks are facilitated, enabling healthcare organizations to track disease trends, detect outbreaks, and predict their spread accurately. This, in turn, aids in the early containment and prevention of infectious diseases (Asrar et al., 2021).

In the field of telehealth and telemedicine, space internet enables patients in remote and underserved areas to connect with healthcare professionals through virtual consultations. Access to healthcare expertise remotely, advice on preventive measures, and routine health check-ups become feasible, particularly crucial in regions where healthcare services are scarce (Shirah et al., 2023).

Space internet technology further extends its impact to tele-surveillance, where individuals are continuously monitored for health changes and disease risks. Enabled by space internet technology, tele-surveillance systems allow healthcare providers to assess various health parameters with precision, offering a comprehensive view of an individual's health (Suresh et al., 2021).

As space internet technology advances, innovative monitoring and prevention strategies become increasingly feasible. The integration of artificial intelligence and machine learning facilitates predictive healthcare models, analyzing vast datasets of patient information to identify health trends, risk factors, and early signs of disease. Proactive interventions based on these models contribute to a preventive and patient-centered approach, ultimately improving health management and patient outcomes (de Hond et al., 2022).

In summary, the integration of space internet technology into healthcare systems heralds a new era of monitoring and prevention. This technology empowers healthcare providers and patients with real-time health monitoring, early disease detection, and proactive interventions, extending to the prevention of infectious diseases. It supports telehealth and tele-surveillance, making healthcare more accessible and patient-centered. As space internet technology evolves and gains broader adoption, it is anticipated to catalyze a fundamental shift in how healthcare is monitored, managed, and prevented, offering vast possibilities for innovative strategies and fostering a healthier and more proactive approach to healthcare (Table 6.4).

Table 6.4 Space internet for monitoring and prevention.

Application area	Monitoring and prevention in healthcare systems
Key technology	– Space internet – Real-time health monitoring – Tele-epidemiology
Key benefits	– Real-time health monitoring – Early disease detection – Prevention of infectious diseases – Remote patient monitoring for chronic conditions – Telehealth and telemedicine – Tele-surveillance and predictive healthcare models
Improvements achieved	– Early detection – Proactive interventions – Remote consultations – Patient-centered healthcare
Future potential	– Fundamental shift in healthcare monitoring and prevention – Innovative strategies – Patient-centered care

Astronaut health beyond earth: the role of space internet in transforming space exploration

The integration of space internet and digital health technologies emerges as a transformative and groundbreaking paradigm in the realm of space exploration, poised to revolutionize healthcare delivery for astronauts during missions beyond Earth. As humanity embarks on ambitious endeavors such as missions to the Moon, Mars, and beyond, ensuring the well-being and health of astronauts becomes paramount. The distinctive challenges and harsh conditions of space travel necessitate innovative solutions to provide quality healthcare services (Mesko, 2018).

Space missions impose stringent demands on healthcare due to the isolation, confined environments, and exposure to extreme conditions (Krittanawong et al., 2022). Astronauts' health is pivotal for mission success, and the space internet plays a crucial role in ensuring timely access to medical expertise. The incorporation of space internet facilitates real-time telemedicine consultations, enabling astronauts to consult with medical professionals on Earth, overcoming vast distances. This technology supports high-quality video conferencing, particularly critical in emergencies, ensuring immediate medical advice. Remote consultations empower astronauts to address health concerns promptly and effectively, elevating healthcare delivery quality during space missions.

Beyond remote consultations, telehealth and telemedicine for preventive healthcare and monitoring constitute integral components of healthcare delivery in space exploration. Wearable devices and sensors continuously collect health data, allowing providers to monitor vital signs and physiological parameters in real-time. This facilitates early detection of health issues and timely interventions, especially valuable during long-duration missions where maintaining astronaut health is paramount (Smith et al., 2023).

In the domain of surgical support, space internet and digital health technologies play a critical role. While surgeries are a last resort in space missions, situations may necessitate interventions. Connecting with expert surgeons on Earth through the space internet enables astronauts to receive step-by-step guidance, surgical instructions, and real-time support, ensuring the success and safety of procedures in space (Pantalone, 2023).

The integration of advanced robotics and telerobotic surgery with space internet technology signifies a transformative phase in space exploration and healthcare. In the expansive realm of space, where conventional surgical methods may fall short, advanced robotics offer enhanced precision, guided by surgeons on Earth through real-time communication facilitated by space internet connectivity. This approach minimizes the risk of errors, crucial in microgravity conditions. The minimally invasive nature of telerobotic surgery is particularly advantageous for astronauts, allowing for faster recovery times in the confined spaces of spacecraft. Augmented and virtual reality technologies further amplify surgical capabilities by providing immersive, 3D visualization. Telerobotic surgery not only addresses medical emergencies but also facilitates planned procedures, reducing the necessity for astronauts to return to Earth for treatment. Despite challenges, the intersection of advanced robotics, telerobotic surgery, and space internet heralds a groundbreaking era, promising safer and more effective healthcare practices for future space missions (Pantalone et al., 2021).

The psychological well-being of astronauts is integral to space exploration, and the space internet contributes to supporting their mental health. The isolation and confinement experienced by astronauts can lead to psychological stress, emphasizing the importance of access to telepsychiatry and psychological counseling sessions via the space internet. Remote mental health support ensures astronauts have the emotional and psychological assistance needed during extended space missions (Smith, 2022).

The integration of space internet technology with telerehabilitation marks a groundbreaking advancement in space exploration, specifically addressing the health challenges faced by astronauts during extended missions. In the unique microgravity conditions of space, astronauts encounter physiological issues like muscle atrophy and bone density loss, necessitating effective rehabilitation. Space internet connectivity empowers telerehabilitation by enabling real-time communication between astronauts and specialists on Earth. This facilitates personalized exercise regimens and remote monitoring of rehabilitation progress. The integration of virtual and augmented reality enhances the rehabilitation experience, making it more engaging for astronauts. Moreover, telerehabilitation plays a crucial role in preparing astronauts for re-entry, addressing the challenges posed by the transition from microgravity to Earth's gravity. While transformative, attention to the reliability of space internet connectivity and the development of space-specific rehabilitation protocols is essential. Overall, space internet-enabled telerehabilitation ensures a holistic and personalized approach to astronaut recovery, emphasizing their health and well-being during and after space missions.

The integration of space internet and digital health technologies into space exploration aligns with the broader objective of enhancing healthcare quality and ensuring astronaut well-being. It improves the efficiency, effectiveness, and accessibility of healthcare services during space missions. Additionally, tele-education and training programs for medical personnel in space missions benefit from space internet technology, promoting continuous medical education and knowledge dissemination within the astronaut corps.

Overall, the integration of space internet and digital health technologies in space exploration signifies a monumental leap in enhancing healthcare delivery and ensuring astronaut well-being beyond Earth. These technologies provide timely access to medical expertise, support remote consultations, enable telemedicine, facilitate remote patient monitoring, offer surgical guidance, and empower telerehabilitation. As space internet technology continues to evolve and gain broader adoption in space exploration, it is expected to catalyze a fundamental shift in how healthcare is provided and accessed in the challenging environment of space, contributing to the success of future missions to the Moon, Mars, and beyond (Table 6.5).

Table 6.5 Space internet and digital health for space exploration.

Application area	Healthcare delivery and well-being for astronauts in space
Key technology	– Space internet – Telemedicine – Telehealth – Telerobotics
Key benefits	– Real-time telemedicine consultations – Remote health monitoring – Surgical support and guidance – Telerobotic surgery for precision – Psychological support for astronauts – Telerehabilitation for physiological issues
Improvements achieved	Enhanced health services, safety, and well-being of astronauts
Challenges	– Reliability of space internet connectivity – Development of space-specific protocols
Future potential	– Fundamental shift in space healthcare – Success of future space missions

Guardians of astronaut health: the role of space internet in extraterrestrial habitats monitoring

The advent of space internet technology heralds significant advancements in the domain of environmental health monitoring on extraterrestrial habitats, representing a crucial milestone in the pursuit of human space exploration and habitation. As humanity's aspirations extend beyond Earth, the imperative for comprehensive and real-time environmental health monitoring of extraterrestrial habitats becomes increasingly pronounced. Space internet technology is positioned to revolutionize environmental health monitoring in outer space, focusing on ensuring safe and habitable conditions for astronauts (Häuplik-Meusburger et al., 2021).

Monitoring environmental health in extraterrestrial habitats presents unique challenges, with the safety and well-being of astronauts dependent on factors such as air quality, temperature, humidity, radiation levels, and the presence of hazardous substances. The dynamic nature of these factors necessitates continuous and real-time monitoring for prompt responses to deviations from desired conditions (Kalapodis et al., 2020). Space internet technology provides essential connectivity and data transmission capabilities, enabling the collection and analysis of environmental data from remote and often isolated habitats.

Real-time environmental health monitoring facilitated by space internet technology empowers mission control and habitat engineers to closely track conditions in extraterrestrial habitats. Parameters like air quality, oxygen levels, carbon dioxide concentrations, and the presence of harmful gases can be continuously monitored. Deviations from safe levels can trigger automated systems or alert on-site personnel for prompt corrective actions, crucial in environments like the International Space Station, where astronauts rely on artificial life support systems.

Monitoring radiation levels is another critical component of environmental health monitoring in space, considering astronauts' increased exposure to cosmic and solar radiation (Furukawa et al., 2020). Space internet technology allows for real-time collection of radiation data, enabling mission control to assess risks to astronauts and issue alerts for them to take shelter in shielded areas promptly. This immediate response is vital in mitigating health risks and ensuring astronaut safety.

The detection of hazardous substances, such as volatile chemicals and biological contaminants, is a concern in enclosed extraterrestrial habitats. Real-time environmental health monitoring can swiftly detect the release of such substances, enabling rapid containment and the protection of astronaut health, preventing potential health crises (Chan et al., 2020).

The application of space internet technology in environmental health monitoring extends to lunar and Martian surface missions, where astronauts require environmental data for informed decisions about exploration and habitat establishment. Real-time monitoring of local conditions, including temperature, atmospheric composition, and radiation levels, ensures the safety of astronauts during surface activities and habitat construction (Heinicke & Arnhof, 2021).

In conclusion, the integration of space internet technology into environmental health monitoring on extraterrestrial habitats represents a pivotal development in human space exploration and habitation. Real-time monitoring of critical environmental parameters is essential for ensuring the safety and well-being of astronauts in space. Space internet technology provides the necessary connectivity and data transmission capabilities for collecting, analyzing, and responding to environmental data from remote and often isolated habitats. As humanity's ambitions for space exploration continue to expand, the adoption of space internet technology in environmental health monitoring is expected to become standard practice, contributing to the success and safety of future missions beyond Earth (Table 6.6).

Table 6.6 Space internet and environmental health monitoring in extraterrestrial habitats.

Application area	Environmental health monitoring in extraterrestrial habitats
Key technology	– Space internet – Real-time monitoring
Key benefits	– Continuous monitoring of air quality, oxygen levels, and hazardous substances – Real-time monitoring of radiation levels – Detection of hazardous substances – Safety assurance for astronauts in space and on planetary surfaces
Environmental parameters monitored	– Air quality – Radiation levels – Temperature – Hazardous substances – Atmospheric composition
Future potential	– Standard practice in space exploration – Enhanced astronaut safety and well-being

For microgravity to medicine: the key role of space internet in space healthcare research

Space internet technology emerges as a key facilitator of real-time medical research aboard spacecraft and space stations, transcending geographical boundaries and enabling seamless collaboration among scientists and healthcare professionals in the challenging conditions of space exploration. In the context of unique health challenges faced by astronauts, such as microgravity-induced bone loss and muscle atrophy, real-time medical research becomes indispensable for comprehending the impacts of space conditions on human health (Hodkinson et al., 2017).

The pivotal role of space internet technology extends beyond immediate astronaut needs, enabling medical experiments and research that contribute to advancements in both space and terrestrial healthcare. Access to up-to-date medical research, collaboration with scientists on Earth, and real-time experiments empower space researchers to delve into drug development, medical imaging, and understanding the biological effects of space conditions. These endeavors not only inform space healthcare but also find applications in terrestrial healthcare, creating a reciprocal exchange that benefits both realms (Shirah et al., 2023).

Global collaboration in medical research is facilitated by the space internet, allowing scientists from various parts of the world to collaborate on space healthcare projects. This interconnectedness transcends borders, uniting the global scientific community in the pursuit of medical research advancements. Collaborative efforts have the potential to yield breakthroughs in space healthcare, leading to the development of novel medical treatments and technologies that ultimately benefit humanity.

The integration of space internet technology into medical research in space marks a significant advancement in space healthcare. Real-time medical research, enabled by high-speed internet connectivity, facilitates experiments, data collection, and collaboration between space and Earth-based researchers. Furthermore, the space internet enhances global collaboration, allowing scientists worldwide to contribute to healthcare advancements for both space and terrestrial applications. As the technology evolves and gains broader adoption, it is poised to catalyze a fundamental shift in how medical research is conducted and applied in the challenging environment of space, ultimately benefiting humanity on Earth (Table 6.7).

Table 6.7 Space internet and real-time medical research.

Application area	Real-time medical research in space
Key technology	– Space internet – High-speed connectivity
Key benefits	– Real-time medical experiments and research – Collaboration with earth-based scientists – Advances in space and terrestrial healthcare
Global collaboration	Facilitated international collaboration in medical research
Future potential	– Fundamental shift in space medical research – Breakthroughs benefitting space and terrestrial healthcare

Toward a digital health transformation: challenges and opportunities in space technology integration

The convergence of space technology and healthcare, particularly in digital health, holds great promise for revolutionizing healthcare delivery, but it faces several challenges. Latency is a foremost concern, with potential delays in data transmission affecting real-time communication and telemedicine. While LEO satellites can mitigate this, addressing latency requires technological enhancements and the development of protocols (Saeed et al., 2020).

Ensuring secure data transmission is critical due to the sensitivity of patient information. Cybersecurity measures and robust regulatory frameworks are essential to protect medical data transmitted via space internet from interference or breaches. Interoperability issues arise from the lack of universal standards for data exchange and device compatibility in digital health applications, necessitating collaborative efforts to establish common formats and protocols (Wu et al., 2023).

Regulatory and ethical challenges involve compliance with healthcare data privacy regulations and addressing ethical concerns in telemedicine. Accessibility and affordability are barriers, and innovative pricing models or subsidy programs are needed to make digital health solutions via space internet financially accessible. Digital literacy and training for healthcare providers and patients are crucial for effective use, requiring educational programs and support mechanisms (Pelton, 2019).

Scalability and infrastructure development pose challenges, especially in regions with limited resources. While space internet can extend healthcare services to remote areas, the associated infrastructure can be expensive and logistically complex. Sustainable business models and public—private collaborations are essential for scalability and overcoming these challenges (Akyildiz & Kak, 2019).

In conclusion, realizing the potential of space internet in digital health requires addressing challenges such as latency, data security, interoperability, regulatory compliance, accessibility, digital literacy, and infrastructure development. Coordinated efforts from governments, healthcare institutions, technology providers, and regulatory bodies are essential for the successful integration of the space internet in digital health, ultimately improving healthcare access and outcomes globally (Table 6.8).

Table 6.8 Challenges and solutions for the application of space internet in digital health.

Challenge	Solution
Latency in data transmission	– Technological enhancements – Protocol development – LEO satellites
Data security and privacy	– Cybersecurity measures – Regulatory frameworks
Interoperability	Collaborative efforts for common standards and protocols
Regulatory and ethical compliance	– Adherence to healthcare data privacy regulations – Ethical considerations
Accessibility and affordability	– Innovative pricing models – Subsidy programs
Digital literacy and training	– Educational programs – Support mechanisms
Scalability and infrastructure development	– Sustainable business models – Public—private collaborations

Blockchain technology in space health records: ensuring security and privacy

The integration of blockchain technology with space health records management presents a promising solution for enhancing the security and privacy of astronauts' medical data in space exploration. Blockchain's transparency, immutability, and cryptographic security address unique challenges posed by extended and remote space missions (Fang et al., 2021).

Blockchain's decentralized ledger ensures the tamper-proof recording of all medical transactions, offering secure and easily accessible health records even in remote space environments. Transparency allows authorized parties, including astronauts, mission control, and medical personnel, to access real-time health records, reducing the risk of miscommunication, crucial for emergency medical situations in space (Mamun et al., 2022).

Immutability ensures the integrity of health data by preventing unauthorized alterations (Cerchione et al., 2023). The cryptographic security of blockchain protects encrypted health records, accessible only by authorized personnel with private keys (Mahajan et al., 2023). This security is vital given the sensitive nature of health data in space missions, minimizing the risk of data breaches (Zaabar et al., 2021).

Blockchain's privacy and consent management features empower astronauts to control access to their health data, crucial in the confined and privacy-limited space mission environment. The decentralized nature of blockchain eliminates a single point of failure, ensuring health records' accessibility, even with limited connectivity to mission control (Saeed et al., 2022).

Despite these benefits, challenges such as integrating blockchain into existing infrastructure, developing user-friendly interfaces, and ensuring interoperability across missions must be addressed. Training astronauts and adapting mission control personnel to this technology are essential steps for successful implementation (Attaran, 2022).

In conclusion, blockchain technology in space health records management represents a significant advancement in space exploration. Its security, privacy, transparency, immutability, and cryptographic features provide a reliable means of managing critical health records, contributing to the well-being and safety of astronauts in the challenging space environment. As space missions evolve, the adoption of blockchain in space health records is expected to become standard practice, ensuring data security and accessibility for future space exploration missions (Table 6.9).

Table 6.9 Blockchain technology in space health records.

Key features	– Transparency – Immutability – Cryptographic security – Privacy – Consent management
Key benefits	– Tamper-proof health record management – Real-time access to health records – Data integrity and encryption – Privacy control for astronauts – Decentralized accessibility in remote environments
Challenges	– Integration with existing infrastructure – User-friendly interfaces – Interoperability across missions – Astronaut training and personnel adaptation
Future potential	– Standard practice in space health records management – Enhanced data security and accessibility for astronauts

Equitable access to space internet: a key to global healthcare

Equity and access to space internet are pivotal in addressing the global digital divide, ensuring that the benefits of enhanced healthcare reach all individuals, regardless of socioeconomic status or geographic location. Bridging the digital divide involves providing universal access to the internet, and satellite-based internet services play a crucial role in reaching remote and underserved regions where traditional infrastructure is lacking.

Equity in space internet extends beyond geographical considerations to affordability, reliability, and inclusivity. Policymakers, governments, and the private sector must collaborate to create regulatory frameworks that support the development and deployment of satellite-based internet while ensuring that access is affordable and reliable for all users. Initiatives subsidizing access costs for underserved populations are instrumental in achieving this goal (Richardson et al., 2022).

In addition to geographical and economic dimensions, equity in the space internet must consider individuals with disabilities, indigenous communities, and other marginalized groups. Designing user-friendly interfaces, providing assistive technologies, and offering culturally sensitive content contribute to making space internet accessible to everyone, fostering inclusivity.

Space internet also plays a crucial role in emergency and disaster response by rapidly restoring communication networks in affected areas, enabling timely coordination and aid delivery. The deployment of satellite constellations and the formulation of comprehensive policies are essential steps toward achieving true equity in access to space internet (Dinas et al., 2015).

In conclusion, by considering the unique challenges and opportunities presented by satellite-based communication systems, efforts can be directed toward creating a more equitable and connected global society. Equity and access to the space internet are fundamental in addressing the digital divide and ensuring that the transformative benefits of enhanced healthcare reach all corners of the world.

Digital health and space internet: pioneering the future of healthcare

The future of digital health in the era of space internet is poised for remarkable growth and innovation. Artificial intelligence and machine learning will increasingly play a crucial role in diagnosing health issues, predicting medical problems, and recommending treatments, enabling more autonomous medical decision-making (Chen & Decary, 2020).

Bioprinting technology presents a groundbreaking innovation set to revolutionize healthcare on Earth and in space. The ability to 3D print medical supplies, artificial organs, and biological tissues offers unique solutions for addressing healthcare challenges, especially in remote or resource-constrained environments (Javaid et al., 2022). This technology could enable astronauts to manufacture customized medical tools and even replace body parts during space missions, ensuring a self-sustaining healthcare ecosystem.

Highly advanced diagnostic tools capable of identifying a wide range of health parameters with unprecedented precision are expected in the future of space healthcare systems. Miniaturized, portable laboratories and diagnostic devices will enable on-the-spot testing, aligning with the principle of remote and point-of-care diagnostics (Heidt et al., 2020). These advancements will enhance healthcare delivery for astronauts and individuals in remote areas on Earth.

Personalized medicine based on genomic profiles is another exciting frontier. As genetic sequencing becomes more accessible, incorporating individuals' genomic information into healthcare management allows for tailored treatment plans, minimizing adverse reactions, and optimizing health outcomes. In space exploration, personalized medicine is particularly beneficial due to astronauts' unique physiological and genetic responses to the space environment (Schmidt et al., 2020).

Overall, the future of digital health in the era of space internet promises a transformative shift in healthcare approaches. The integration of artificial intelligence, bioprinting, advanced diagnostics, and personalized medicine will enhance healthcare delivery for both astronauts and individuals on Earth. As we continue to explore space, digital health will remain a critical component, offering solutions that transcend the boundaries of our home planet and improve well-being both in space and on Earth. The future of digital health holds the promise of a healthier, more connected, and more personalized approach to healthcare, benefiting individuals in both terrestrial and cosmic environments (Table 6.10).

Table 6.10 Future directions in space internet and digital health.

Key innovations	Role in healthcare	Applications
Artificial intelligence and machine learning	Autonomous medical decision-making	Enhanced space healthcare
Bioprinting technology	Customized medical tools and body part replacement	Remote and resource-constrained healthcare solutions
Advanced diagnostic tools	On-the-spot testing and remote diagnostics	On-the-spot testing for astronauts and remote areas
Personalized medicine	Tailored treatment plans and health optimization	Individualized healthcare based on genomic profiles

Space internet revolution: transforming healthcare in Asia and the Gulf region

In Asia and the Gulf region, where vast populations often face challenges related to geographical isolation and uneven access to healthcare services, the integration of space internet technology becomes particularly significant. The amalgamation of space internet technology with healthcare in regions such as Asia and the Gulf inaugurates a transformative epoch for healthcare systems, addressing enduring challenges in healthcare delivery within remote and underserved areas. The dynamic nature of these regions, coupled with the widespread challenges of geographical isolation, infrastructure constraints, and financial limitations, makes the space internet a compelling solution to enhance healthcare accessibility.

The advantages of the space internet extend prominently to addressing emergency healthcare needs in remote locales. Swift access to healthcare expertise becomes pivotal in critical medical situations, and high-speed internet provision through satellite networks ensures timely assistance from healthcare professionals during emergencies. Real-time transmission of medical data, images, and videos enhances medical decision-making, substantially improving patient outcomes, particularly in regions lacking immediate access to specialized medical care.

Beyond emergency care, preventive healthcare and disease management also stand to benefit significantly from space internet technology. Chronic patients in these regions, often residing in remote areas, can receive continuous health monitoring through wearable devices and telemonitoring solutions. Transmitting vital health data to healthcare providers facilitates early issue detection and timely interventions. Digital health applications deployed via the space internet contribute to remote patient education, medication management, and lifestyle coaching, fostering healthier living in underserved communities.

Moreover, the integration of space internet technology opens novel avenues for the prevention of infectious diseases, a concern that resonates strongly in regions marked by global health crises. Swift sharing of epidemiological data, tele-epidemiology, and rapid response to infectious disease outbreaks are facilitated, enabling healthcare organizations in Asia and the Gulf to track disease trends, detect outbreaks, and predict their spread accurately. This, in turn, aids in the early containment and prevention of infectious diseases, contributing significantly to public health in these regions.

In the field of telehealth and telemedicine, space internet enables patients in remote and underserved areas in Asia and the Gulf to connect with healthcare professionals through virtual consultations. Access to healthcare expertise remotely, advice on preventive measures, and routine health check-ups become feasible, particularly crucial in regions where healthcare services are scarce.

As space internet technology advances, innovative monitoring and prevention strategies become increasingly feasible for Asia and the Gulf Region. The integration of artificial intelligence and machine learning facilitates predictive healthcare models, analyzing vast datasets of patient information to identify health trends, risk factors, and early signs of disease. Proactive interventions based on these models contribute to a preventive and patient-centered approach, ultimately improving health management and patient outcomes.

In summary, the potential of space internet to transform digital health in Asia and the Gulf region is vast and multifaceted. The integration of space internet technology addresses the unique challenges faced by these regions, offering solutions for emergency care, preventive healthcare, disease management, and the prevention of infectious diseases.

Conclusion

This chapter illuminates the transformative potential encapsulated within the future of digital health during the era of space internet. Despite the challenges presented by cybersecurity, regulation, and equitable access, the promise of improved healthcare outcomes and expanded medical service access stands as a beacon of excitement and revolution. The integration of space internet into digital health aligns harmoniously with the overarching goal of cultivating a more equitable and accessible healthcare landscape, holding the power to bridge existing healthcare disparities. As we navigate through these pioneering advancements, the convergence of space technology and healthcare unfolds a future where the very essence of healthcare is redefined, monitored, and accessed in ways that not only benefit individuals on Earth but also extend its positive impact to the far reaches of the cosmos. In contemplating this transformative journey, it becomes evident that the synergy between the space internet and digital health is poised to shape a future where healthcare becomes a universal right, transcending boundaries and enriching lives across the expanse of our shared existence.

For policymakers, this shift in healthcare dynamics brought about by the integration of space internet calls for proactive engagement. Recognizing the profound implications of this transformative duo, policymakers play a critical role in crafting regulatory frameworks that safeguard cybersecurity, ensure equitable access, and foster responsible innovation. By addressing these challenges head-on, policymakers can create an environment conducive to the ethical and secure deployment of space internet technology in healthcare. Moreover, strategic policy initiatives that incentivize research, development, and adoption of space-internet-driven healthcare solutions can propel nations toward a future where healthcare disparities are diminished. Policymakers hold the key to harnessing the full potential of these technological advancements to create a healthcare landscape that is not only advanced but also just and accessible to all.

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CHAPTER 7

Sleep stage classification using a convolutional neural network based on heart rate variability features

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Introduction

Sleep quality is an important factor for both physiological well-being and mental health, which is generally measured by assessing time, performance, and safety (Stein and Pu, 2012). One of the key factors influencing the quality of sleep is the adequate amount of sleep obtained. Insufficient quality of sleep has the potential to yield an array of detrimental consequences to one's health, including but not limited to symptoms of fatigue, anxiety, diminished energy levels, poor concentration, compromised motor system function, susceptibility to sleep disorders, and even the possibility of mortality (Tibbitts, 2008). The incidence of sleep disorders, namely shift work sleep disorder, insomnia, and sleep apnea, may be mitigated through the attainment of high-quality sleep, Moreover, by taking preventive measures aimed at mitigating the exacerbation of sleep disturbances, the likelihood of detecting and treating sleep disorders may improve.

Therefore, it is very important to monitor a person's sleep quality and detect sleep disorders. Sleep disorders can be prevented by identifying the stages of sleep. Sleep stages of humans consist of awake, non-rapid eye movement (NREM), and rapid eye movement (REM). NREM consists of light sleep (which is divided again into stage 1 and stage 2) and deep sleep (which is divided again into stage 3 and stage 4) (Oropesa et al., 2000).

Sleep stage identification usually can be done by a sleep specialist. The patient is required to sleep in the provided room with the associated devices. Common devices used are electroencephalographic (EEG) for measuring brain waves and electrocardiogram (ECG) for measuring heart rate. The device used in this research is ECG because its installation is more comfortable than EEG.

The data obtained from the ECG will be extracted with features from heart rate variability (HRV) such as time domain, frequency domain, and geometrical and Poincare plot (Oropesa et al., 2000; Camm and Malik, 1996; Karim et al., 2010), then these features are

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used to build a classification model. Neural networks are suitable to be used to form classifier models because of their fault-tolerant nature compared to other classifiers. Neural networks are also suitable for analyzing biomedical signals because of their variety of applications and their ability to study complex and nonlinear relationships (Erguzel et al., 2015).

The convolutional neural network (CNN) is a reliable computational algorithm that uses the concept of neural network, The CNN algorithm has gained broad usage in various domains, including but not limited to image processing, signal processing, language analysis, and automatic speech recognition. The utilization of CNN with data derived from the ECG sensor gives the best accuracy. A prior study (Chen et al., 2019) carried out sleep-wake detection using features from HRV, showing that CNN provides high-accuracy results without feature selection.

This study has proposed a novel investigation of sleep stage classification aimed at examining the accuracy of the classification for sleep quality. The proposed method of this study uses the ECG sensor with feature extraction from HRV and Deep Learning with the CNN algorithm for classification. In addition, CNN and hyperparameter tuning were implemented to attain optimal accuracy outcomes.

Literature review

In this section, we discuss some related research. Xiao et al. (2013) researched the classification of sleep stages, which are divided into three classes, namely awake, REM, and NREM. The data used is the Sleep Heart Rate and Stroke Volume Data Bank (SHRSV), which consists of 45 healthy recording subjects, aged 16 to 61 years, and consisting of 28 men and 17 women. Every 30 seconds, the data is annotated by a sleep specialist into 6 classes, namely awake, REM, and stages 1, 2, 3, and 4 of NREM. Before entering the feature extraction stage, a preprocessing stage is carried out to detect the RR location. A total of 41 features were extracted in this research.

In another work, Yildirim et al. (2019) conducted research on sleep stage classification using polysomnography (PSG) signals with a one-dimensional convolutional neural network (1D-CNN) model. Ozal extracts EEG and EOG signals from the PSG dataset. Ozal then divides the dataset into two, namely sleep-edf and sleep-edfx. Sleep-edf consists of 15,188 data samples and sleep-edfx consists of 127,512 data samples. Each dataset is divided into classes for training, namely 2 classes (awake-sleep), 3 classes (awake-sleep-REM), 4 (awake-{S1-S2}-SWS {S3-S4}-REM), 5 (awake-S1-S2-SWS {S3-S4}-REM) and 6 (awake-S1-S2-S3-S4-REM). From the simulation results, accuracy performance was obtained at 97.62%, 94.34%, 92.33%, 90.98%, and 89.54% for 2 to 6 class classifications, respectively.

Singh et al. (2016) created an alternative approach to detect sleep stages for the home so as not to disturb the patient's comfort. Jaspal uses an ECG dataset, where he uses REM and NREM methods based on features selected and then extracted from the ECG signal.

The data taken are LF/HF, DFA, sampEN, and Poincare. The classification algorithm used is a support vector machine with three classes, namely; light sleep, deep sleep, and REM. The simulation results show an accuracy of 76.25% with a Cohen's kappa (κ) of 0.52 for the two-class classification model for a 5-minute signal. The results drop to 72.8% accuracy and $\kappa = 0.48$ for the two-class classification model for one-minute signals.

(Boostani et al., 2017) conducted comparative research on sleep stage methods in patients. During research, he used a dataset of EEG signals. The classification algorithm used is the random forest classifier for five classes of sleep stages classification, which are; wake, N1, N2, N3, and REM. Before carrying out classification, Reza carried out feature extraction of data using the time domain, frequency domain, time-frequency domain, and nonlinear features. Feature selection is applied after the feature extraction stage to find a subset of discriminative features. The goal of additional feature selection is to obtain a minimum number of features without redundancy while yielding higher accuracy. So it is expected that it can reduce the computing time. According to the results achieved in both groups, the wavelet coefficient entropy along with the random forest classifier was selected as the best feature and clustering, respectively. The simulation results show an accuracy of 87.06% in the healthy group and 69.05% in the sick patient group.

Mitsukura et al. (2020) conducted sleep stage detection research using heart rate. The research aimed to develop an easier method for measuring sleep objectively. Yasue divides it into five classification classes, namely wake, N1, N2, N3, and REM. The classification algorithms used are RNN and HMM. The simulation results show the accuracy of RNN = 66% and HMM = 63.3% for data from 50 subjects.

Yulita et al. (2018) created a sleep stage classification approach with a multi-layer perceptron algorithm. Before carrying out classification, Intan carries out preprocessing, taking the data that wants to be processed, namely EEG, EMG, and EOG for sleep stage classification. The classification results with the proposed MLP model are 79.4% compared to Naïve Bayes = 59.2%, Bayes Network = 68.3%, Decision Tree = 73.5%, and KNN ($k = 5$) = 66.5%. The Multi-Layer Perceptron algorithm achieves better accuracy than other classification algorithms.

Surantha et al. (2021). identified sleep stages using HRV features, namely time domain, geometrical, Poincare, and frequency domain, using extreme learning machine (ELM) with pseudo swarm optimization (PSO) as a classification model. PSO is used to get random combinations of features to get optimal results. The data used is MIT-BIH PSG. The total features used are 18 features. This feature is considered the best feature based on the results of previous research literature studies. In this study, evaluation was carried out for 4 types of classes, namely 2 class classification (awake and sleep), 3 class classification (awake, NREM, and REM), 4 class classification (awake, light sleep, deep sleep, REM), and 6 class classification (awake, stage 1, stage 2, stage 3, stage 4, and REM). The accuracy results obtained for the classification of 2, 3, 4, and 6 classes were 82.1%, 76.77%, 71.52%, and 62.66%, respectively.

Some researchers have conducted sleep stage classification using deep learning. Chen et al. (2019) carried out sleep-wake detection classification with CNN using features from HRV data and accelerometer data, classifying only two classes, namely sleep and wake, and the accuracy obtained was 76%. Wei et al. (2018) conducted sleep stage classification research using ECG sensors from the MIT-BIH Polysomnographic dataset, the classification model used was a deep neural network (DNN) to classify three classes of sleep stages. The accuracy results obtained were 77%.

Based on the previous study, there is room for improvement in sleep stage classification using HRV, especially for 3, 4, and 6 class classification. There are also still few researchers that conducted the classification using deep learning techniques. Therefore, in this research, we will conduct sleep stage classification using one of the deep learning techniques, which is CNN.

Methods

This step consists of a dataset from the MIT-BIH Polysomnography Database, preprocessing data to remove unused data. Feature extraction based on HRV features and build model. The model used is CNN, and the last one is a hyperparameter.

Dataset

The dataset was obtained from the PhysioNet data center, named MIT-BIH Polysomnographic Database (Goldberger et al., 2000). The data contains a collection of recordings capturing the subject's physiological signals while sleeping, namely ECG signals, EEG signals, blood pressure, respiration, etc. In this study, the data used were only the ECG signal which had a sampling frequency of 250 Hz and 12 bits/sample. The data consisted of 18 recordings from 16 people, each recording having a different duration. Subjects' ages range from 32 to 56, with a mean age of 43. Additionally, the weight ranged from 89 to 152 kg with a mean weight of 119 kg. Before undergoing the process of preprocessing, the dataset consisted of a total of 10,274 samples, whereby each sample was recorded as having a length of 30 seconds.

Preprocessing data

The recorded data comprises two distinct categories, namely RR interval and annotation data. RR interval consists of the time difference between two consecutive R waves of the ECG signal. The Annotation data pertains to the sleep stage that has been labeled by a sleep specialist for every 30-second recording. In the preprocessing stage where there are some invalid data, i.e., no annotations, the annotations are not by the research, they will be removed.

Feature extraction

The next step is feature extraction based on HRV features. The ECG is a device that has abilities to record and interpret electric impulses of the ECG information containing HRV data (Joshi and Tomar, 2014). The HRV feature is extracted as much as possible to provide uniqueness or to give HRV an attribute from each sample. The techniques used are Time Domain, Geometrical, Poincare, and Frequency Domain. The total features used in this research were 18 features. Table 7.1 shows the total features list of HRVs that will be used in this study.

Convolutional neural network method

In building a classifier model using 1D CNN. 1D CNN is known to be suitable for inputting data in one dimension, such as biomedical signals (Yildirim et al., 2019).

Table 7.1 Features list.

Method	No.	Feature	Description
Time Domain	1	AVNN	The average of all RR intervals
	2	SDNN	The standard deviation of all RR intervals
	3	RMSSD	The square root of the average of the sum of the squares of differences between adjacent RR intervals
	4	SDSD	Standard deviation of differences between adjacent RR intervals
	5	NN50	The count of adjacent RR intervals differences that are more than 50 ms *Number of* $RRj + 1 - RRj > 50$
	6	pNN50	The division of NN50 by the total of all RR intervals minus one times 100
Geometrical	7	HRV Triangular Index	The total number of RR intervals divided by the peak of histogram created from RR intervals data with 7.8125 bin size
Poincare	8	SD1	The standard deviation of points perpendicular to the axis of line of identity
	9	SD2	The standard deviation of points along the axis of line-of-identity
	10	SD1SD2 Ratio	Ratio of SD1 and SD2
	11	S	Area of ellipse $S = \eta \times \mathrm{SD1} \times \mathrm{SD}$
Frequency Domain	12	TP	Total power
	13	LFnorm	Normalized LF
	14	HFnorm	Normalized HF
	15	LFHF Ratio	Ratio of LF and HF
	16	VLF	Total power of 0–0.04 Hz
	17	LF	Total power of 0.04–0.15 Hz
	18	HF	Total power of 0.15–0.4 Hz

For 1D input, S and W kernel input signals, the convolution operation is defined as follows:

$$(S * W)_n \sum_{i=1}^{|W|} W(i)S(i+n-1) \tag{7.1}$$

Where the operator * denotes a discrete convolution operation and the kernel is also called weight. The output of the convolution is called a feature map. $(S_{|W(i,j)})_n$ be a finite matrix from the input matrix to the weight matrix. element $(S_{|W(i,j)})_n$ represents the element S from n to the dimension $W(i, j)$. Thus, the output matrix can be represented by the general formula, which is given in Eq. (7.2):

$$O_n^l = (S_{|W(i,j)} * W(i,j))_n \tag{7.2}$$

This convolution layer operation is similar to feature extraction, and the output generates an input feature map. The last layer of the CNN model usually contains a neural network layer, called the fully connected layer and this layer performs classification tasks. The CNN model that will be built has 18 layers, details can be seen in Fig. 7.1.

To build a CNN model, the library to be used is MatConvNet, a special CNN library using the Matlab program (Vedaldi & Lenc, 2015). In the process of constructing a CNN model, the matching of the dataset to be used and the reference model is carried out, such as the layer model from AlexNet and GoogleNet, which perform convolutions exceeding four iterations. Failure to adhere to this criterion runs the risk of overfitting in the dataset, where the convolution is more than four times. The layer model is tuned to fit the dataset to be used. The total of CNN layers used is 18 layers,

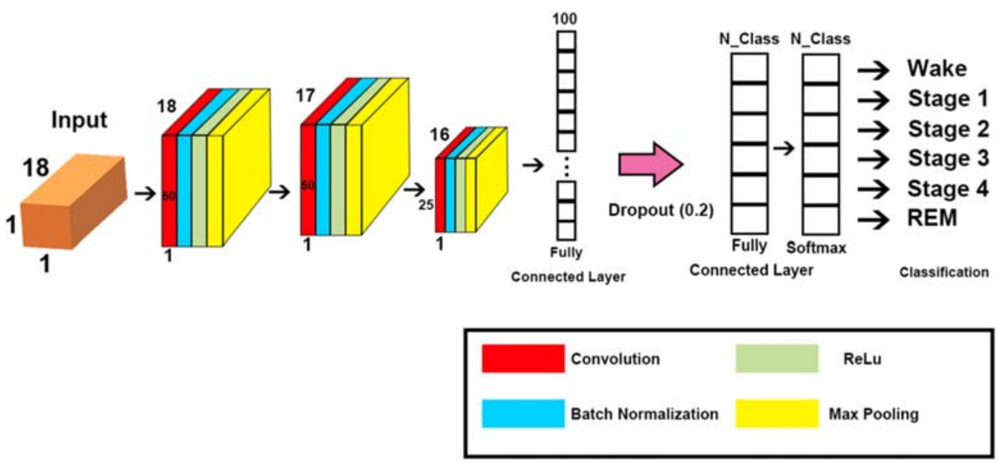


Figure 7.1 Convolutional neural network model.

after the convolution layer is processed with Batch Normalization for stability in the training, the convolution process is carried out 3 times followed by Batch Normalization, ReLu, and Max Pooling, on the Dropout Layer parameter input is 0.2 this for to prevent overfitting problems, then the Fully Connected Layer to combine all process results from the convolution, finally the Softmax Layer calculates the probability of each target class over all possible target classes and will help to determine the target class for a given input (N_Class).

Hyperparameter

Upon construction of the CNN model, tuning of the hyperparameters is processed to enhance the accuracy outcomes and attain an optimal solution. In the study (Yildirim et al., 2019) several inputs from the hyperparameter were used, namely the batch size is 16 and 32, the learning rate is 0.0001, and compared to batch size 64 and the learning rate is 0.00001 the optimizer used is the adam optimizer in 3-layer CNN and epoch is used 100 times. Where a batch size of 32 and a learning rate of 0.0001 give good results. This paper tries to use three different input hyperparameters, namely the Adam optimizer which doesn't change its input, uses hyperparameter tuning from Yildirim et al. (2019), and finally tries to set input hyperparameter.

Results

The data is classified into 2, 3, 4, and 6 classes classification, wherein the class members are (1) awake and sleep, (2) awake, NREM, and REM, (3) awake, deep sleep, light sleep, and REM, (4) awake, stage 1, stage 2, stage 3, stage 4, and REM. For data validation, the method used is split validation with 70% training data and 30% for testing. The data is retrieved for each class proportionally. This study was carried out utilizing a personal computer equipped with Windows 10 Pro 64-bit, 256GB SSD M.2 NVME, 8GB 2666Mhz DDR4 (2x4GB), AMD Ryzen 5 3600, NVIDIA RTX 2060 GPU.

Preprocessing data result

In the preprocessing step, some data that have no annotation, incomplete RR interval, or non-relevant annotation were removed. There are 120 or about 1.17% data removed. Based on those remaining data, the next step is synchronizing RR interval and annotation data, feature extraction, and data normalization.

Hyperparameter test scenario

In Table 7.2. This is the hyperparameter testing scenario that will be used for the CNN model. In this research, experiments will be carried out on the CNN model with three different input hyperparameters.

Table 7.2 Hyperparameter input.

Parameter input	Hyperparameter scenario 1	Hyperparameter scenario 2	Hyperparameter scenario 3
	Inputs used		
Optimizer	Adam optimizer	Adam optimizer	Adam optimizer
Batch size	128	32	32
Learning rate	0.001	0.0001	0.001
Epoch	30	100	100

Convolutional neural network first scenario

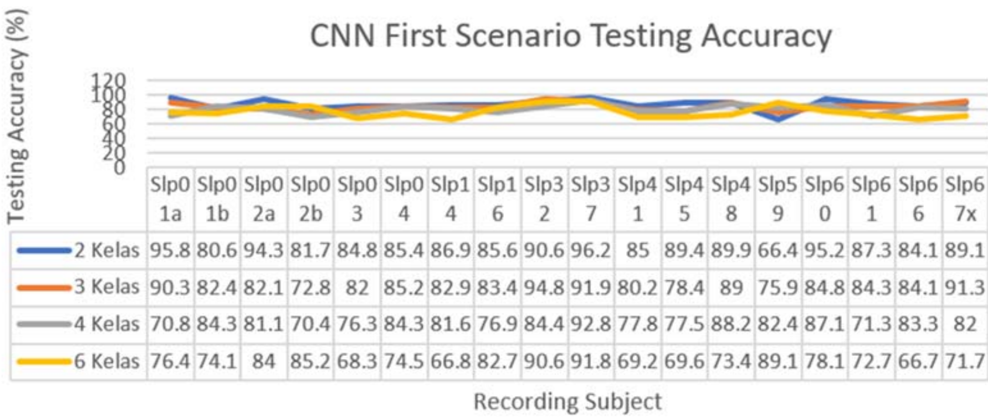
The first experiment scenario was trying to use the CNN method approach with hyperparameter tuning derived from Adam Optimizer. In particular, hyperparameters derived from the Adam Optimizer, namely a batch size of 128, a learning rate of 0.001, and epochs were carried out 30 times in this experiment for each recording result and each number of classes. Based on the experiments, the average training accuracy for 2, 3, 4, and 6 classes is 91.33%, 89.33%, 86.39%, and 83.44%, respectively. The average of testing accuracy for 2, 3, 4, and 6 classes is 87.13%, 84.21%, 80.69% and 76.93%, respectively. The result shows the difference between testing and training accuracy is 4.2%, 5.12%, 5.7%, and 6.51% for 2, 3, 4, and 6 classes, respectively (Fig. 7.2).

Convolutional neural network second scenario

The second experiment scenario tries to use the CNN method with hyperparameter tuning from (Yildirim et al., 2019), the input hyperparameter used is the Adam optimizer with several input changes such as a batch size of 32, a learning rate of 0.0001 and epochs carried out 30 times at this experiment for each record result and each number of classes. Based on this, the average training accuracy for 2, 3, 4, and 6 classes is 91.06%, 87.56%, 83.50%, and 77.44%, respectively. The average testing accuracy for 2, 3, 4, and 6 classes is 88.37%, 83.03%, 81.00% and 71.57%, respectively. The result shows the difference between testing and training accuracy is 2.69%, 4.53%, 2.5%, and 5.87% for 2, 3, 4, and 6 classes, respectively (Fig. 7.3).

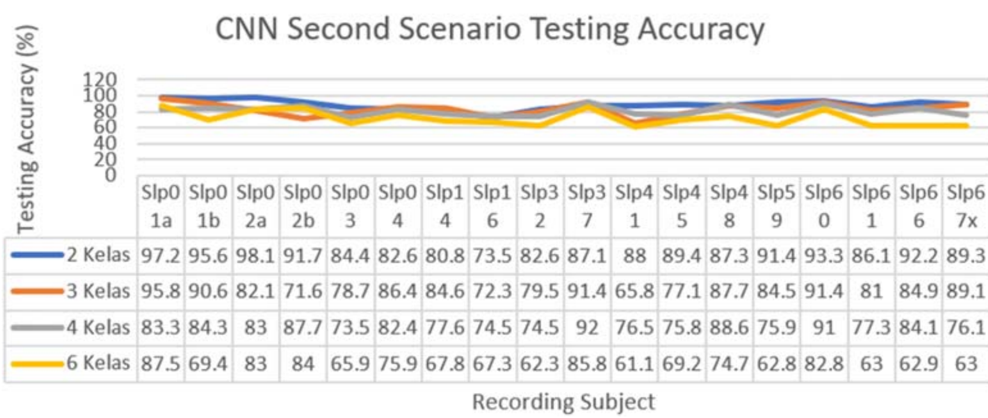
Convolutional neural network third scenario

The third experiment scenario tries to use the CNN method with hyperparameter tuning from the two experiments above, the hyperparameter input used is Adam optimizer with several input changes such as a batch size of 32, a learning rate of 0.0001, and epochs were carried out 30 times in this experiment for each result record and



	Slp01a	Slp01b	Slp02a	Slp02b	Slp03	Slp04	Slp14	Slp16	Slp32	Slp37	Slp41	Slp45	Slp48	Slp59	Slp60	Slp61	Slp66	Slp67x
2 Kelas	95.8	80.6	94.3	81.7	84.8	85.4	86.9	85.6	90.6	96.2	85	89.4	89.9	66.4	95.2	87.3	84.1	89.1
3 Kelas	90.3	82.4	82.1	72.8	82	85.2	82.9	83.4	94.8	91.9	80.2	78.4	89	75.9	84.8	84.3	84.1	91.3
4 Kelas	70.8	84.3	81.1	70.4	76.3	84.3	81.6	76.9	84.4	92.8	77.8	77.5	88.2	82.4	87.1	71.3	83.3	82
6 Kelas	76.4	74.1	84	85.2	68.3	74.5	66.8	82.7	90.6	91.8	69.2	69.6	73.4	89.1	78.1	72.7	66.7	71.7

Figure 7.2 Convolutional neural network first scenario accuracy result.



	Slp01a	Slp01b	Slp02a	Slp02b	Slp03	Slp04	Slp14	Slp16	Slp32	Slp37	Slp41	Slp45	Slp48	Slp59	Slp60	Slp61	Slp66	Slp67x
2 Kelas	97.2	95.6	98.1	91.7	84.4	82.6	80.8	73.5	82.6	87.1	88	89.4	87.3	91.4	93.3	86.1	92.2	89.3
3 Kelas	95.8	90.6	82.1	71.6	78.7	86.4	84.6	72.3	79.5	91.4	65.8	77.1	87.7	84.5	91.4	81	84.9	89.1
4 Kelas	83.3	84.3	83	87.7	73.5	82.4	77.6	74.5	74.5	92	76.5	75.8	88.6	75.9	91	77.3	84.1	76.1
6 Kelas	87.5	69.4	83	84	65.9	75.9	67.8	67.3	62.3	85.8	61.1	69.2	74.7	62.8	82.8	63	62.9	63

Figure 7.3 Convolutional neural network second scenario accuracy result.

each class number. Based on this, the average training accuracy for 2, 3, 4, and 6 classes is 95.94%, 91.17%, 88.06%, and 82.72%, respectively. The average accuracy of testing for 2, 3, 4, and 6 classes is 95.15%, 89.37%, 86.03% and 78.77%, respectively. The result shows, the difference is quite small for 2, 3, 4, and 6 classes, which are 0.79%, 1.8%, 2.03%, and 3.95% (Fig. 7.4).

Experiment result and comparison

These results indicate that the CNN in the third experiment has a higher accuracy result than the CNN from the first experimental scenario and second experimental scenario (Table 7.3). The difference in the accuracy of CNN in the third experimental scenario and the first scenario is 7.42%, 5.16%, 5.34%, and 1.84% for the results of each class. The difference in the accuracy of CNN for the third and second

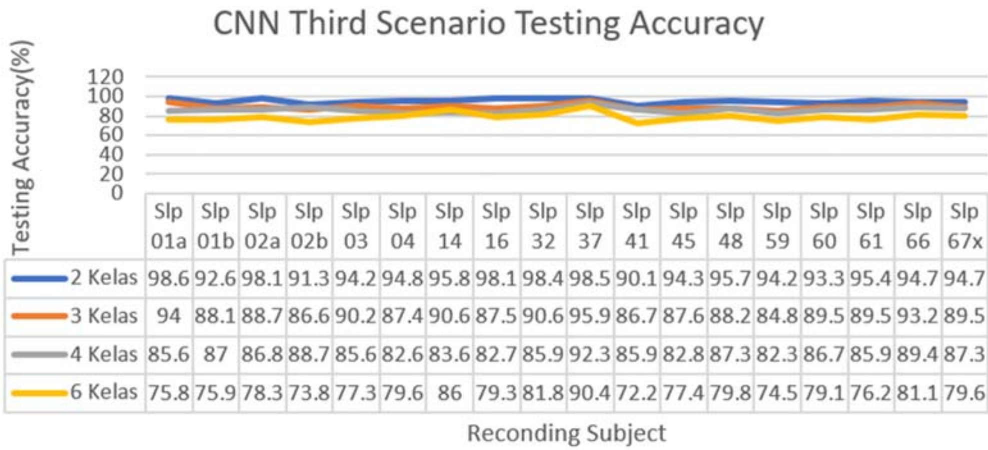


Figure 7.4 Convolutional neural network third scenario accuracy result.

experimental scenarios is 6.78%, 6.34%, 5.03%, and 7.2% for the results of each class. In Table 7.2. The best performance in two classes is 95.15% in the CNN third scenario, and the worst performance is in six classes with an accuracy of 71.57% in the CNN second scenario. The third scenario CNN experiment gives higher accuracy than the others but takes about 7 minutes to process.

Methods comparison

Table 7.4 shows a comparison of proposed CNN method with other methods that use the same dataset and features.

Based on the comparison of the accuracy results obtained, CNN has higher accuracy than other methods, where the accuracy results of the ELM and PSO methods are lower than the CNN method, the support vector machine (SVM) and PSO methods provide accuracy results below ELM and PSO, accuracy increases by about 20% for each class with CNN, compared to DNN for 3 class accuracy, the accuracy increases by 12%, then CNN provides about 14% higher accuracy than the ELM and PSO methods.

Conclusion

This study involves the construction of a classifier model utilizing time domain, geometry, Poincare and frequency domain techniques applied to ECG and HRV signal features. The method used as a classifier is a method with hyperparameter tuning and creating thre test scenarios. Each model was constructed for 2, 3, 4, and 6 classes and was evaluated using the average accuracy of each subject. The results show that the third scenario CNN provides the highest average accuracy among the other two test

Table 7.3 Experiments result.

		Precision	Recall	f1 score	training accuracy	testing accuracy	Time
2 Classes	CNN third scenario	97.02	94.79	97.73	95.94	95.15	417
	CNN first scenario	91.28	90.68	90.77	91.33	87.73	84
	CNN second scenario	91.81	92.73	89.76	91.06	88.37	174
3 Classes	CNN third scenario	90.66	87.33	94.68	91.17	89.37	428
	CNN first scenario	91.72	88.80	89.71	89.33	84.21	78
	CNN second scenario	89.01	84.85	89.20	87.56	83.03	176
4 Classes	CNN third scenario	87.71	81.68	87.40	88.06	86.03	427
	CNN first scenario	85.64	83.53	84.59	86.39	80.69	83
	CNN second scenario	87.04	80.24	78.80	83.50	81.00	176
6 Classes	CNN third scenario	82.41	78.92	82.59	82.72	78.77	410
	CNN first scenario	79.45	73.21	80.01	83.44	76.93	84
	CNN second scenario	80.08	71.74	78.80	77.44	71.57	173

Table 7.4 Methods comparison.

Methods	Accuracy 2 class	Accuracy 3 class	Accuracy 4 class	Accuracy 6 class
CNN third scenario (proposed)	95.15	89.37	86.03	78.77
DNN (Wei et al., 2018)	—	77.00	—	—
ELM & PSO (Fennia Lesmana et al., 2018)	82.10	76.77	71.52	62.66
SVM & PSO (Fennia Lesmana et al., 2018)	78.38	74.10	68.53	58.05
ELM (Fennia Lesmana et al., 2018)	78.12	72.20	66.83	57.62
SVM (Fennia Lesmana et al., 2018)	72.2	66.94	62.52	51.66

scenarios but requires a longer processing time. CNN has been observed to possess the capacity to mitigate the likelihood of overfitting of the model. For future research, is interesting to explore the combination of CNN with the LSTM method to further improve the prediction accuracy.

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CHAPTER 8

Application of artificial intelligence and digitalization in medical education and various surgical specialities: concerns and prospects

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Introduction

COVID-19 has accelerated the adoption of digital technology, with governments worldwide recognizing its potential benefits such as economic growth, worker productivity, and universal healthcare access. The Asia Pacific Region, including Japan, Korea, Singapore, and Thailand, is facing challenges due to an ageing population. Countries like Japan, the Republic of Korea, Singapore, and Thailand have made significant strides in digitization and health promotion through national information and communication technologies (ICT) and health promotion policies (World Population Prospects, 2022). The COVID-19 pandemic has accelerated the integration of digital technology into daily routines, highlighting the importance of embracing digital technology for healthy aging. Digital healthcare has also gained interest, with the World Health Organization recommending telemedicine adoption (The Telecommunication Development Sector, 2022; World Population Prospects, 2022). However, India faces challenges such as a lack of data protection rules, privacy concerns, and a comprehensive framework for informed consent. The adoption of digital healthcare is crucial for a digital society and a healthier future.

Defining digital health

Digital health, defined by the World Health Organization, involves the integration of digital technologies in healthcare delivery, including big data, genomics, artificial intelligence, and eHealth. It involves the use of ICT to optimize treatment outcomes,

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enhance diagnostic precision, and improve chronic disease monitoring (Nishith Desai Associates Digital Health in India, 2020; World Health Organization, 2019).

AI can be used to examine "symbolic models of diseases" and assess their correlations with patient symptoms, providing valuable insights for various purposes such as diagnosis, treatment, medical protocol development, drug discovery, and patient monitoring. AI can execute human functions faster and cheaper, potentially reinvigorating modern healthcare. AI-powered medical tools include virtual assistants, MelaFind in the US, robotic-assisted therapy, and Caption Guidance (Pai et al., 2021).

Access to healthcare can be made more rights-based using digital healthcare models, which can radically alter the healthcare delivery system. Rights-based approaches, grounded in the participation, accountability, non-discrimination, empowerment, and legality (PANEL) (Pai et al., 2021; Reddy, 2018) principles of public health literature, transform human rights from theoretical concepts to legally binding obligations. Access to healthcare based on the right to care necessitates individual responsibility and health decision autonomy is grounded in the right to freedom, dignity, privacy, security, and physical integrity (Jain & Tronic, 2018). However, a rights-based approach has inherent limitations, as it is grounded in a supposedly universal "Western" framework and may perpetuate hierarchies if used without considering disparities in socioeconomic, cultural, and political contexts. Therefore, healthcare delivery models based on indigenous rights that prioritize social and cultural aims are required (Shalev, 2000).

Telemedicine in India

Telemedicine consultations in India have been available for some time, but the lack of a legal framework has hindered their supply. The Karnataka State Medical Council issued warnings to physicians about potential hazards associated with online consultations, which could lead to their professional registration revocation (Yasmeen, 2019). The government announced the Telemedicine Practice Guidelines on March 25, 2020, coinciding with India's statewide lockdown in response to the COVID-19 epidemic (Myupchar, 2020). These guidelines aim to provide doctors with practical guidance in incorporating telemedicine into their routine practice for all services and models of care.

Patients must provide accurate information during teleconsultations, which clinicians must treat as in-person consultations. Doctors can teleconsult with patients via phone, mobile, WhatsApp, Facebook Messenger, mobile apps, or internet-based platforms, but must use their professional judgment (Medical Council of India Telemedicine Practice Guidelines, 2020). Teleconsultations can be conducted with caregivers, even in the absence of the patient if the patient is under 16 or unable.

Prescriptions should be done by video and provided via email, WhatsApp, or other methods (Medical Council of India Telemedicine Practice Guidelines, 0). There is no universally accepted structure for prescriptions, and the guidelines propose developing one. They address difficulties with permission, ethics, and consultation tools in high-risk settings, such as minors under 16 or those with physical or mental disabilities. Physically challenged patients may speak with doctors, but children may not disclose their health to caretakers, potentially resulting in inaccurate information.

Surgery and digitalization

Introduction

The success of surgical procedures is often evaluated by clinical outcomes like morbidity and mortality. However, patient feedback on the efficacy and safety of surgical procedures is increasingly being considered. Patient-reported outcome measures (PROMs) are scientifically proven tools that can effectively capture patients' viewpoints, such as health-related quality of life, symptom severity, and care experiences (Liu et al., 2019; Panda et al., 2022). A study involving 1324 patients from 17 hospitals in the United States and Canada surveyed 1324 patients, who had 348 different types of surgery (Barbash & Glied, 2010). The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) deployed its platform to collect PROMs during a pilot project. The study found that it is possible to use the ACS NSQIP to evaluate PROMs after only a preliminary implementation and assumes that it can overcome challenges. Comprehensive evaluation of PROMs has the potential to inform diagnosis, treatment, recuperation, and survival. Mobile health apps could be used to roll out these initiatives, and PRO data has been shown to aid in symptom management, assessment of innovative treatments, and evaluation of healthcare's value and quality in medical and surgical cancer (Liu et al., 2019; Panda et al., 2022).

Future of surgical robotics and artificial intelligence

In 2016, Shademan and colleagues demonstrated the practical feasibility of an autonomous soft-tissue surgical robot, the Smart Tissue Autonomous Robot (STAR), in vivo. The STAR system, which uses AI and optical and tactile sensors, performed comparably with human surgeons in controlled studies (Esteva et al., 2017; Rajpurkar et al., 2017). This marks a significant milestone in surgical robotics. The field of AI clinical data diagnostics has made significant advancements, with studies showing its performance is comparable to professional physicians. Both medical and nonmedical experts are keen on clinical AI. The STAR studies highlight the usefulness of clinical AI in surgical procedures, with potential implications for autonomous surgical equipment development. To achieve widespread adoption, it is crucial to rationalize the evolution of these procedures and ensure they offer technological or financial benefits compared to existing surgical methods.

Human control versus autonomy

ISO 8373:2012 defines autonomy as the ability to perform predetermined tasks without human intervention, based on current conditions and sensing capabilities. Variable autonomous robotic surgical equipment, such as the DaVinci system by Intuitive Surgical, TSolution-One orthopedic robot, and Mazor X spinal robot, operate on a "master-slave" principle, relying entirely on human control. Accuray's CyberKnife system, a semiautonomous clinical robot, uses external radiation beams for procedures, distinguishing it from a "surgical robot." These technologies demonstrate the potential of variable autonomy in surgical procedures (Panesar et al., 2019).

Controlling and teaching the robot

The robotic system in a surgical setting must be able to perform tasks effectively and adapt to the dynamic environment. Its proficiency is attributed to its ability to process sensory inputs, accurately assess the environment, and quickly convert this into robotic actions. Machine learning (ML), a subfield of AI, allows machines to learn from previous data and command autonomous machinery. Trained algorithms enable robots to make real-time predictions and perform tasks (Kassahun et al., 2016; Moustris et al., 2011).

ML is a powerful tool for processing vast and complex datasets, enabling robots to adapt their behaviors based on environmental changes and training. If the accuracy of sensory data is comparable to human senses, these algorithms may surpass human perception in predicting or identifying undesirable events. AI has shown effectiveness in detecting diseases by analyzing radiological data, but the process of collecting and analyzing diverse sensory information to mimic human surgeons' perceptual capabilities in real time is more complex.

Robots can be "taught" surgery through direct programming, observation, or virtual reality (VR) training. To mimic a human surgeon, robots must be able to evaluate all sensory inputs and positional feedback, and understand the surgical goal. This requires using implicit and explicit procedures in conjunction with domain experts to reinforce and alter them (Kassahun et al., 2016). A robot's learning pace is limited by its hardware and software capabilities, but human learning potential is limited by mental, physical, and time constraints. In summary, ML offers significant benefits for robots in complex datasets, but their learning potential is limited by various factors.

Autonomous robotic surgery in adverse environments

Telemedical solutions under human control may be unfeasible in scenarios like space exploration, conflict areas, or environmental catastrophes due to transmission latencies and bandwidth constraints. For example, a 2.5-year Mars exploration mission with communication delays of 4—24 minutes could be unmanageable due to crew medics' lack of training (Panesar & Ashkan, 2018). If technological advancements allow, a fully autonomous surgical procedure could be conducted, or a partially autonomous approach, like the STAR trials, could be employed, where individuals with basic medical expertise handle access and closure tasks, while robots handle more complex procedures.

Increasing global access to surgical care

The da Vinci robot, the most popular commercial robotic surgery system since 2000, faces substantial acquisition and maintenance costs. Competitors are expected to advance robotics and reduce expenses, making autonomous surgical equipment financially viable. Cost reductions, technology improvements, and clinical and public market adoption may make it affordable for emerging economies and neglected medical environments. As early designs with few users are expensive, economies of scale may make them affordable (Barbash & Glied, 2010; Novellis et al., 2017).

Intensive care and health digitalization

The demand for healthcare and ICU medication is increasing faster than society can afford due to chronic diseases and aging populations. Digital technologies and automation have improved productivity in manufacturing, but medicine has not yet fully benefited. Digital twins, or model-based optimization of production systems and equipment, are growing rapidly, allowing for more efficient and effective medical care. This concept, combined with model-based decision support and control in clinical settings, can tailor care to each patient, increasing efficiency and effectiveness. The complexity and individuality of ICU patients make them challenging to care for, necessitating improvements in output and care quality (Dombovy, 2002; Halpern & Taichman, 2009; Halpern et al., 2011; van Exel et al., 2015).

Surgical training and digitalization

Mobile applications can significantly enhance surgical trainees' cognitive abilities outside the operating room, improving their chances of success. They provide immersive simulation experiences using computer-generated visuals or surgical video, enhancing the realism of simulations (Knol & Keller, 2018; Luengo et al., 2018). Using surgical footage and graphical overlays can also provide additional educational value. Explanatory labeling, annotations, and multiple-choice questions enhance teaching. New surgical technologies are being developed and validated, and two platforms are available for minimally invasive general surgery (Naveed et al., 2018). Laparoscopic abdominal surgery is less suitable for this technology due to its lack of pneumoperitoneum and ventilation, which some abdominal organs need to move. The platform includes modules for training in Transanal total mesorectal excision of the rectum (TaTME) and laparoscopic hepatic resections, with a mobile application for easy website usage. The TaTME modules incorporate cognitive training using surgical footage that can be repositioned on the mobile device (Huber et al., 2019). This application is useful for post-CCT (Certificate of Completion of Training) fellowship trainees, those interested in colorectal surgery, and hepatobiliary surgery trainees who have performed liver resections before CCT (Intercollegiate Surgical Curriculum Program, 2017; Joint Committee on Surgical Training, 2017).

Digital Surgery Ltd.'s Touch Surgery (TS) is a mobile software that simulates surgery on a smartphone or tablet, teaching and testing surgical knowledge and decision-making through cognitive task analysis (TouchSurgeryTM, 2020). It offers computer-generated and surgical video simulations for all surgical specialties, including index cases. A study of 51 medical students and 54 surgeons showed that TS laparoscopic cholecystectomy modules have face, content, and construct validity (Kowalewski et al., 2017). Chidambaram et al. found that students in the TS module group had better cognitive performance than those in the control group, with a mean performance score of 41.9 ± 22.5 compared to 24.7 ± 19.6 ($p = 0.016$). The group randomized to TS had higher cognitive performance for laparoscopic cholecystectomy steps (initial exposure, initial dissection, cystic duct dissection, cystic artery dissection, and gallbladder fossa dissection) but was not statistically significant (Chidambaram et al., 2019).

Digitalization and medical education

The SARS-CoV-2 outbreak in 2020 disrupted traditional medical education, leading to the adoption of eLearning, internet webinars, and learning platforms. A study by Wolf et al. (2022) found that 192 German university students switched to digital media for their medical education. Lectures were recorded and made available to students, and seminars were held biweekly via online webinars. An online exam was administered at the end of the internship. A survey was conducted at the end of the academic term, evaluating past and current experiences with eLearning and exploring potential future development towards a fully digital university. 88% of students transitioned to web-based lectures, and 77% changed their approach to studying due to the digitization of the classroom. A total of 73% agreed that eLearning lectures should be delivered regularly, and 54% found them more comprehensible than live lectures. A total of 41% of students have considered attending an entirely online university.

The impact of the pandemic on surgical education, student acceptance of digitization, and the future extension of virtual instruction remain uncertain.

In the field of surgery, traditional classroom lectures are insufficient for practical subjects like surgery. To maintain a systematized approach to pedagogy, novel methodologies have been developed, such as digitized surgical training lectures for medical students. Webinars are useful for teaching medical topics as they allow problem-based learning in small groups (Serebrakian et al., 2020; Sura et al., 2017; Wagner et al., 2019). Bidirectional communication is essential for surgical learning and prerecorded on-demand lectures have replaced traditional theoretical lectures. Recorded lectures provide advantageous outcomes, as they allow students to process content at their own pace. The implementation of pauses during lectures allows students to engage in self-directed learning, allowing them to progress at their own pace (O'Callaghan et al., 2017). This approach is particularly beneficial during the viral pandemic, as it allows for better communication and retention of information (Nkomo & Daniel, 2021).

VR and augmented reality (AR) can be used to create a practical educational environment, transforming traditional learning methods into a digital one (Chen et al., 2020; Kyaw et al., 2019). These technologies have become more affordable, but rapid implementation can be challenging for some students. Surgical training can be made more cost-effective through webinars and remote lectures. Despite the COVID-19 pandemic, many students have adopted digital learning, largely due to increased flexibility and reduced commuting times. Nearly half of students prefer face-to-face classes, and 40% support a digital university education (Amir et al., 2020; Dost et al., 2020; Khalil et al., 2020). Hybrid teaching concepts combining face-to-face courses with digital technologies like webinars, AR/VR, and remote lectures can enhance general medical practice education. This approach can teach theoretical information, examination procedures, operation assistance, and basic surgical manual skills. However, practical skills are challenging to learn, and new formats for teaching practical skills are needed to maintain contact limits for extended periods (Chen et al., 2020). Despite the advancements in digital technology, traditional teaching methods remain insufficient for enhancing the learning experience for medical students.

Digitalization and women's health

Digital diagnostic technologies are crucial in obstetrics and gynecology for detecting diseases and improving diagnostic accuracy. Modern techniques can assess the functional state of the female reproductive system, identifying factors contributing to menstrual disorders, infertility, and other reproductive system complications. AI and ML are emerging trends in digital diagnostics, improving the speed and accuracy of diagnostic processes. Iftikhar et al. (2020) reviewed the potential of AI in improving diagnostics, treatment approaches, and patient outcomes in obstetrics and gynaecology (OB/GYN) (Iftikhar et al., 2020). However, they noted that additional research is needed to address bias in algorithm development and incorporate new medical knowledge and emerging technologies. Practitioners should prioritize measures to ensure the reliability and accuracy of their analysis, and AI should not replace skilled professionals. The use of patient records in AI systems raises ethical concerns about patient confidentiality, as they require extensive data to make accurate predictions.

Artificial intelligence and women's perspectives on mental healthcare

In a study conducted by Reading Turchioe et al. (2023), the attitudes of women towards AI-based technologies in mental healthcare were investigated. The online survey revealed that 258 participants expressed openness towards AI technology, but also expressed concerns regarding potential medical harm and inappropriate sharing of data (Reading Turchioe et al., 2023). The responsibility for harm was attributed to clinicians, developers, healthcare systems, and the government. The majority of participants highlighted the significance of comprehending the output generated by AI, particularly pregnant individuals who emphasized the limited role of AI in mental healthcare. The study proposes that trust in AI-based technologies for mental healthcare among women can be enhanced through measures such as safeguards against harm, transparency in data usage, maintenance of patient-clinician relationships, and ensuring patient understanding of AI predictions. Qasrawi et al. (2022) study demonstrates the efficacy of ML methods in predicting maternal depression and anxiety among pregnant and postpartum women amidst the COVID-19 pandemic. The study determined that these models effectively identified risk factors that impact maternal mental health (Qasrawi et al., 2022). The utilization of these models has the potential to facilitate the creation of health prevention and intervention programs that improve maternal and child health in low- and middle-income nations. The study indicates that employing ML models for early detection and screening of these problems could be a valuable asset for enhancing maternal and child health.

Fetal heart monitoring and pregnancy surveillance

Fetal heart rate (FHR) monitoring is crucial in identifying high-risk challenges in labor, describing baseline FHR, variability, acceleration, deceleration, uterine contraction intensity, and pattern alterations. AI can be used to analyze cardiotocographs and estimate outcomes during labor, reducing obstetricians' intrapartum monitoring interpretation disparities and minimizing neonatal and maternal problems and morbidity. AI systems can provide supporting evidence in unanticipated adverse situations that could lead to litigation. In 2018 Guijarro-Berdiñas B evaluated the computer-aided fetal evaluator (CAFE) evaluated an AI system to interpret CTG data, showing it read information like experts and detected flaws (Guijarro-Berdiñas & Alonso-Betanzos, 2002) observed that disputes between specialists prevented the study from proving its optimality and precision. The INFANT study protocol (Brocklehurst, 2016) which was aimed to evaluate the potential of AI in assisting healthcare practitioners in selecting the most appropriate management approach for individual patients by analyzing computerized interpretation of FHR during labor. The objective is to enhance the reliability of FHR readings, assist physicians in interpreting and making decisions, and increase efficiency to alleviate job burden. this study concluded that the Implementing a dependable FHR monitoring system has the potential to enhance healthcare and decrease instances of perinatal asphyxia on a global scale (Brocklehurst, 2016).

AI technology, combined with telemedicine, can detect issues early and provide a safe monitoring system for both clinicians and patients. The study also alerts patients to concerns about FHR levels and directs them to contact their doctor. Neural network recognition techniques were used to resolve specialist interpretation differences. The study found that doppler ultrasonography with AI is cost-effective and avoids false notifications of fetal threat. However, a larger study is needed to replicate the results and confirm this intervention.

Kazantsev et al.'s study on maternal and infant mortality suggests that AI home monitors can be used for outpatient care to monitor high-risk patients (Kazantsev et al., 2012). This technology, combined with telemedicine, can detect issues early and provide a safe monitoring system for both clinicians and patients. The study also alerts patients to concerns about FHR levels and directs them to contact their doctor. Neural network recognition techniques were used to resolve specialist interpretation differences. The study found that doppler ultrasonography with AI is cost-effective and avoids false notifications of fetal threat. However, a larger study is needed to replicate the results and confirm this intervention.

Gestational diabetes mellitus

Gestational diabetes mellitus (GDM) screening is costly and burdensome for pregnant mothers, and AI can help discover conventional replacements. The US Preventive Services Task Force recommends a 50 g oral glucose challenge test after 24 weeks gestation and a second diagnostic test (Polak & Mendyk, 2004). However, data is insufficient to screen before 24 weeks gestation. An AI calculator to screen for GDM was tested by Polak and Mendyk, which was found to be more cost-effective and patient-friendly than current standards (Final Recommendation Statement, 2020). The calculator uses an algorithm-back propagation model and uses risk factors such as high blood pressure, hyperlipidemia, smoking, weight, low-fat diet, and ethnicity. The artificial neural network (ANN) model learns and advances as exposed to more cases, lowering health expenses, though AI is less effective than traditional screening tests. Its ease of usage makes it useful for daily use (Andrew & Isaac, 2018).

Preterm labor and artificial intelligence

Short cervical length is a significant risk factor for preterm birth, but many mothers still give birth at full term. Amniocentesis is used to identify inflammation and infection risk factors in patients. Metabolomics, a method using amniotic fluid analysis, can identify new indicators of preterm birth. This method is more effective than using short cervical length and past preterm birth to assess the risk of preterm birth. Bahado-Singh et al. (2019) used AI, amniotic fluid proteomics and metabolomics, imaging, demographic, and clinical variables to predict prenatal outcomes in asymptomatic women with short cervix length. The study used an AI system with deep learning capabilities, which can process larger neural networks. Further research is needed to understand the omics of amniotic fluid and the mechanisms of premature cervix shortening to improve therapeutic interventions.

Ovarian cancer screening and digitalization

Neural network models are being used to improve ovarian cancer prognosis, as the disease is heterogeneous and has significant variations in histology and inpatient presentation. Norwitz (2006) reported a 97% accuracy rate in predicting survival using an online calculator for both physicians and patients, called an ANN. These AI systems can also predict the most effective treatment for individual patients based on their diagnosis, which is crucial due to the unfavorable long-term survival rates associated with advanced ovarian cancer.

Ovarian cancer, a prevalent gynecological cancer, is not currently screened, leading to a significant 5-year mortality rate. An AI neural network has been developed to detect almost all ovarian cancer abnormalities, helping control the disease. An AI system has been developed to scan ovarian cancer cells to identify patients at a heightened risk of developing aggressive tumors (Enshaei et al., 2015). This system can detect irregularly shaped nuclei, which indicate tumor aggressiveness. Combining AI-based scanning with routine biopsies can help detect DNA instability risk factors and select appropriate treatments. Misshaped nuclei in aggressive ovarian cells indicate immune system evasion, suggesting a response to immune-targeted treatments. AI has also surpassed human experts in interpreting cervical precancer images, overcoming the need for a Papanicolaou smear specimen and acetic acid for tissue whitening (Using Artificial Intelligence to Detect Cervical Cancer, 2020). AI deep learning algorithms can accurately identify diseased tissue on a vast array of images, making the test convenient, accurate, and cost-effective.

Fertility and digitalization

Guh et al. (2011) developed a data mining (DM) and AI method to predict in-vitro fertilization (IVF) pregnancy outcomes. DM reduces irrelevant data and identifies outcome-affecting factors, boosting usable data. They developed a hybrid intelligence model that combines genetic algorithm-based learning approaches with decision-tree learning techniques to extract information from IVF patient records. This algorithm predicts outcomes and suggests IVF treatment based on individual patients. However, the model only employed data from one IVF center, which could be improved by sharing data from multiple centers. Manna et al. (2013). suggested using AI to extract texture descriptors from a local binary pattern and an ANN to construct it. This strategy has the potential to aid in the noninvasive and objective selection of the best oocytes or embryos, even in countries that ban sex-based embryo selection. Overall, DM and AI can improve IVF outcomes and improve patient outcomes in IVF centers.

Applications of artificial intelligence in orthopedic surgery

Introduction

Orthopedic surgery is a medical specialty that treats pathological and traumatic diseases affecting bones, joints, and connective tissues. magnetic resonance imaging (MRI) is an essential tool in the diagnosis of soft-tissue injuries due to its high sensitivity, specificity, and positive/negative prognostic value. Machine-based imaging research, such as radiography and computed tomography, is ideal for this field due to its clear visualization of skeletons and subtle skeletal diseases. The integration of imaging data in orthopedic surgery and other relevant fields will greatly benefit from these advancements. Computer orthopedic diagnosis and management algorithms have also gained more capabilities in recent years.

Joint reconstructions

Automated image-based diagnosis

MRI has been used in various studies to diagnose arthritis, with Ashinsky et al. (2017) using the ML technique WND-CHRM to identify medial femoral condyles prone to progression to symptomatic osteoarthritis (OA). The model demonstrated a sensitivity of 74% and specificity of 76%, but had limitations in sample size. Pedoia et al. (2019). developed a comprehensive knee model using DenseNet, a densely connected convolutional neural network (CNN), to diagnose knee OA before observable radiographic alterations. The model achieved a sensitivity of 76.99% and specificity of 77.94% when considering patient demographics, such as age, gender, body mass index (BMI), and Knee injury and Osteoarthritis Outcome Score (KOOS). Both studies have shown potential in detecting OA early.

Xue and Üreten developed a VGG-16 deep CNN to autonomously detect hip OA from radiographs in the US. The model had 95% sensitivity and 90.7% specificity, similar to a trained physician (Üreten et al., 2020; Xue et al., 2017). This approach emphasizes radiologic aspects that enhance diagnosis, building physician faith in the model. Orthopaedics has prioritized using ML to automate imaging investigations for OA detection and staging due to its high prevalence. Kim et al. (2020) and Swiecicki et al. (2021) have utilized AI to classify OA severity, using radiographs and the Kellgren–Lawrence grading system. Their Faster R-CNN model was as accurate as radiologists and more reproducible. Kim's deep learning approach improved AUCs by merging picture data with patient demographics and medical history.

Automated implant evaluation

Borjali et al. (2019) developed a deep CNN model to detect mechanical loosening in hip implants, a common cause of arthroplasty implant failure. The model, trained with 94% sensitivity and 96% specificity, outperformed an experienced orthopedic surgeon in detecting loosening from radiographs. Yi et al. utilized ResNet deep CNN to aid in preoperative planning for knee arthroplasty (Yi et al., 2020). The study classified knee radiographs by presence or absence of arthroplasty, total vs. unicompartmental knee arthroplasty, and implant product manufacturer. The ML approach could save surgeons time during revision case preoperative planning.

Trauma and artificial intelligence

Olczak et al. (2017) study utilized AI for fracture identification in trauma orthopedics, using five deep learning networks to detect fractures in 256,000 radiographs. The best network correctly identified laterality, body part, exam view, and fracture, with 83% of fractures detected.

Deep learning networks trained using radiographic images have achieved precise detection accuracies for fractures, with CNNs detecting femoral neck, intertrochanteric hip, and distal radius fractures with 94.4%, 95.5%, and 96% accuracy, respectively (Gan et al., 2019; Urakawa et al., 2019). These algorithms have been applied for detecting fracture subtypes and functional classification, particularly in fractures of proximal humeral, calcaneal, and pelvic bones (Chung et al., 2018; Krogue et al., 2020; Pranata et al., 2019).

Orthopedic surgeons, including Lindsey (Lindsey et al., 2018), have found that neural networks can improve detection accuracy. Lindsey's study showed that deep neural networks significantly increased clinician sensitivity and specificity in emergency fracture detection, from 80.8% to 91.5% and 87.5% to 93.9%, respectively. This led to a 47% decrease in incorrect interpretations, demonstrating the potential of neural networks in the field.

The research by Olczak and Urakawa (Urakawa et al., 2019) showed impressive results, but their final accuracies were significantly influenced by input processing quality, such as image cropping. Urakawa's study showed that smaller cropped images improved diagnostic accuracy compared to whole hip radiographs. However, deep learning networks could not provide contextual diagnosis or prognostication due to the lack of clinical knowledge synthesis in training sets. Despite these limitations, AI has the potential to revolutionize trauma orthopedics diagnosis once these limitations are overcome.

Prediction of outcome and artificial intelligence

Karnuta and Ramkumar's study utilized a Bayesian machine learning algorithm to predict hip fracture patients' length of stay and cost based on age, ethnicity, gender, and comorbidities (Karnuta et al., 2019; Ramkumar et al., 2019). This data was used to propose a patient-specific, tiered bundled payment model that balances payor and institution risk sharing. Although the Bayesian algorithm only predicted the most likely payment strata for each patient, it demonstrated its intersubspecialty applicability in predicting orthopedic patient outcomes, a potential application in other medical fields in the future.

Stojadinovic's study utilized a Bayesian classifier to predict the success of extracorporeal shockwave therapy in trauma prognosis (Stojadinovic et al., 2011). The study found that time to therapy and bone type were the best predictors of treatment outcome. However, this therapy is only used on fractures that failed first-line procedures, making AI prognostication studies for surgical or immobilized fracture patients scarce.

Soon, it might be fascinating to follow the progress of AI use in orthopedics, including whether it will encompass other imaging modalities beyond radiographs, other functional applications, and other therapeutic modalities.

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SECTION III

National healthcare visions and digital transformation of healthcare services and infrastructures in Asia

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CHAPTER 9

Telehealth services for aging patients in Pakistan: Understanding challenges and developing regionally relevant support through social policy

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Geriatric care in Pakistan

The aging population in Pakistan, above the age of 60 years, is estimated to stand at 15 million people (David et al., 2022), and with population growth rates of almost 2%, the increase in this population group is expected to be 30 million by 2030 (Ashiq & Asad, 2017). Local scientific research suggests that the health burdens facing elderly people are immense and include issues of mental health (Mumtaz et al., 2021), chronic disease and comorbidities (Naz et al., 2021), and general health ailments related to aging (Ashiq & Asad, 2017). Healthcare services for aging people in the country can be classified as almost abysmal, with no state tertiary care centers having dedicated geriatric care or wards, limited geriatric specialist providers, and no geriatric health workforce in the primary set-up (Mazhar et al., 2018; Noreen et al., 2021; Saqib et al., 2018). Negligence of the aging population's health stems from a combination of low prioritization by the state and exclusion of the study of geriatrics as a specialization in the medical education sector. The current healthcare budget stands at less than 0.8% (Muhammad et al., 2023), and with extreme political and financial instability in the country (Ashraf, 2023), there is little hope for investment in geriatric care for the aging population. This is where telehealth services assume great significance in creating inclusion and access for elderly patients in Pakistan who may not have the finances, transport, or other means to visit a health center.

Pakistani society is dominated by the ethic that elders must remain at home and be taken care of by their families. This is why there are very few care homes for the elderly in the country, and the few that do exist in the large urban cities have few

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residents, with minimum standards for quality of care for the elderly (Vertejee et al., 2020). Some scientific research confirms that elderly care homes in the country offer almost no health services or regular check-ups for the residents (Rizvi Jafree et al., 2022a). The majority of the elders who live at home face their own share of problems such as loneliness, isolation, abuse, and having less support for visiting health providers and follow-up for health maintenance (Cassum et al., 2020). The majority of aging people in the country are impoverished (Jalal & Younis, 2014) or have shrinking savings due to rapid inflation (Khan et al., 2018), which prevents them from having adequate finances for health and wellbeing. The fact that elderly people are also deprived of universal health services and health insurance means that the majority of the poor and aging population in the country is dependent on the limited out-of-pocket finances they may have or on generous family and relatives for their health needs (Shaikh & Ali, 2023). State social support in the form of a universal pension or subsidization of transport, utilities, and food for the elderly is also nonexistent, which influences the quality of life among the aging population, and ultimately also impacts their health (Matthews et al., 2023; Nasir et al., 2021). The combination of social isolation, nuclearization of families, and poverty also prevents the elderly from engaging in capacity-building activities, developing skills in digital literacy and accessing digital resources.

Telehealth services for the elderly in Pakistan

The COVID-19 pandemic necessitated developing nations such as Pakistan to deliver care to patients through telehealth, despite issues of technological poverty (Jabeen & Rabbani, 2023). However, telehealth remained accessible for select patients receiving services from the tertiary sector in urban cities, with poor and rural-based population groups remaining bereft due to a lack of technological access and internet availability (Jaffe et al., 2021). Upscaling telehealth services remains a problem throughout Pakistan, primarily due to limited stakeholder efforts and government investment (Manzoor, 2021). Isolated interventions with limited services have shown success in the uptake of telehealth by the elderly in the country, but there has been no attempt to understand or research the satisfaction or challenges faced by patients and providers (Mahdi et al., 2022). The majority of elderly people in the country face low digital literacy, lack of independent access to technology and Wi-Fi, and high dependence on relatives for technological support (Khan et al., 2022).

Recent scientific research highlights that emergency provision of telehealth during COVID-19 brought minimum benefits for the elderly due to the lack of access to technology by the majority, but also the influence of health-seeking behaviors of those elderly persons who did have such access (Saleem et al., 2023). Elderly people had a negative response to government-imposed isolation and suffered greater trauma, anxiety, and depression due to fear of the unknown and quarantine; hence their uptake of telehealth and willingness for repeat online consultancy was low. Another study suggests that telehealth is only accepted by the youth in Pakistan, and exclusive provision of telehealth for elderly populations without in-person health services may compel older people to seek healthcare from unlicensed or traditional providers (Achakzai et al., 2023).

Achakzai et al. (2023) also argue that when telehealth has been offered in urban areas, there have been technical problems regarding internet connectivity and physicians not being trained for managing online services, which prevents continued uptake and trust in the system of telehealth. Another local study concludes that telehealth has to be easy to manage and budget-friendly for the elderly, otherwise, it can become a cause of more stress for aging patients (Feroz et al., 2023). There is fear that expanding telehealth services without consideration of the challenges faced by elderly patients will adversely impact uptake and, thereby, lead to inequity. This contribution seeks to investigate the challenges in delivering and receiving telehealth services for aging patients in Pakistan. For this paper, telehealth is understood as the remote provision of health care via video calls, whilst the provider and the patient do not meet physically or in person. The semistructured questionnaires prepared were derived from theories, literature review, and consultation with elderly people (who had received telehealth services) and their providers.

The *Technology Acceptance Model* suggests that two main factors that determine whether telehealth will be accepted by patients are "perceived usefulness" and "perceived ease of use" (Davis et al., 1989). Both patients and providers will have different perceptions of usefulness and ease of use, depending on their age, level of experience with technology, type of disease, and perceived comfort in using technology. There is concern that users who are older and less experienced with the use of technology and video calls will have less acceptance of telehealth. This also means that when providers and patients are forced into a situation, for example during pandemics or facing limited transport, where they must engage with telehealth, their quality of meeting time and consultancy will be negatively impacted due to low personal acceptance.

The *Theory of Reasoned Action* suggests that human action is determined by mental constructs such as "attitude" and "subjective norms" (Ajzen, 1980). Patients and providers who have negative attitudes regarding technology in general, and who traditionally have not been using technology in their daily lives, will consequently have fewer positive attitudes towards telehealth. Elderly patients are sometimes known to have less trust in technology and even suffer from technological anxiety (Meng et al., 2022), which can affect their health uptake and recovery when having to receive telehealth services.

The *Action Network Theory* suggests that goals are achieved through a network of faithful alliances consisting of humans and nonhumans interacting together

(Callon, 1986). In the case of telehealth services, there is a system of people and technology working together to deliver positive health outcomes, which includes: (1) interaction between provider, coordinator, and patient, (2) interaction with technology, such as smartphones, computer equipment, and Wi-Fi, and (3) interaction between the patient and relatives or care providers, supporting elderly with technological communication. Healthcare providers are known to be burdened with having to coordinate with multiple agents during the delivery of healthcare services, such as other providers, coordinators, patients, and family attendants in the hospital setting (Brouwers et al., 2017). Telehealth services now compound the coordination and work burden for providers and may affect their ability to deliver the best services for aging patients facing multiple and acute health issues (Kaplan & Litewka, 2008).

The *Transaction Cost Theory* states that the goal of any service is to minimize the costs associated with transactions (Hajli et al., 2015). Therefore, the provider or patient will choose or commit to telehealth based on costs and perceived benefits of the expense. Providers who feel that they are not being remunerated enough and the patient is not gaining the best service may limit telehealth meetings or deliver suboptimal services through telehealth (Kazmi et al., 2022). On the other hand, elderly patients who feel that the expense of telehealth is not providing them with the services they have paid for will have less satisfaction with telehealth and also avoid its use (Iqbal & Khan, 2017).

In the following section, we are going to present the results of a qualitative study in this context. This study received ethics clearance from the ethical board of Forman Christian College University, Lahore, Pakistan. Data was collected by telephone after gaining informed consent. The sample included elderly patients above the age of 60 years who had received telehealth services through public sector hospitals or private telehealth clinics in Pakistan. A total of five healthcare providers delivering telehealth services and twenty-one elderly patients receiving telehealth services were interviewed. Provider and patient responses were transcribed, and thematic analysis was used to derive themes related to challenges and barriers to optimal health delivery and patient satisfaction.

Providers' challenges in delivering telehealth services

Technological problems and telehealth staff inefficiencies

Healthcare providers indicated facing technological issues during telehealth services, even though they had telehealth staff and coordinators to support them. One gastroenterologist shared that though teleclinics are cost-effective and remove transport barriers for the poor populations, "[. . .] sometimes the sound is not working, or there are signal Wi-Fi issues. Patients from rural and remote areas especially do not have steady internet or sound quality. In many cases, we have to switch to audio call because of this." There were complaints about inefficiencies of the technical staff, which compromised patient care, with one provider explaining: "The telehealth staff is overworked and understaffed. There are time delays related to this, which affects communication, management, and follow-up with patients."

Negative effect on work-life balance

Some providers revealed that hospital coordinators were not able to schedule all calls when the provider was at the workplace and shared their direct numbers with patients. A cardiologist said: "Our mobile numbers have been shared for WhatsApp video calls when we are at home," resulting in violation of home-work balance for providers, along with issues of greater work burden without a salary increase: "Our work has increased now with patients expecting us to respond to texts [...] sometimes daily and at all odd hours. Obviously, we are not getting compensated for this extra work."

Inability to assess physical characteristics of patients and confirm diagnosis

Many providers felt that with elderly patients there was even more need to meet and assess their physical characteristics, such as their weight, strength, and movement. This was important not just to confirm a diagnosis for new patients, but also to assess the progress of existing clients. An orthopedic consultant explained: "Touching the area of the bone where it may be fractured is needed to reach proper diagnosis. Also, the summary or description of elderly patients is never adequate, compared to younger adults." Another provider, a gastroenterologist, shared that, depending on the patient, there was need for monthly physical assessment, which was only possible at the clinics: "Treating patients with chronic liver disease requires measuring their weight and assessing their strength and movement during in-person consultancy."

Delays in treatment and lack of follow-up by the patient

Providers shared that there were delays in treatment and a lack of follow-up by patients due to telehealth services. A hepatologist explained that: "If we advise patients in teleclinic to get an X-ray or blood test, we have to wait for them to get those investigations done, and in most cases, there is a delay of 3–4 days or even weeks. However, if they are in the hospital, we can direct them to the X-ray ward or blood test window and there isn't as much delay in diagnosis and start of treatment." An orthopedic surgeon explained that elderly patients who depended entirely on telehealth were at risk of adverse events and long-term disabilities: "At the height of the pandemic, there were incidents of elderly patients having falls and fractures. We asked them to mask up and get an X-ray done, but they were unable to come. They were thus advised basic treatment like painkillers. This has resulted in long-term problems such as malunited fractures and patients becoming permanently bedridden. Even now, some patients insist to treat them through telehealth as they have no one to bring them in—this is dangerous for their recovery."

Not suitable for new patients and should not be considered a substitute for in-person visits

A nephrologist confirmed that telehealth was just not an option for certain health conditions: "As far as my specialty is concerned, we simply cannot rely on telephonic delivery, we require one-on-one interaction with patients, clinical examination, and investigations." The advice by most providers was that telehealth must be carefully considered for some patients only if their baseline history was known and physical visits had been conducted initially: "Telehealth is only fine for patients who need minor consultancy or those needing palliative support and minor adjustment of their medications." Ultimately, providers felt that telehealth should not be considered or promoted as a substitute for in-person visits, especially for elderly patients who may face unpredictable health patterns and adverse health risks: "Telehealth is an excellent service but must not be considered a substitute for elderly patient management. It should be an option only when [an] in-person visit is not possible, or for minor follow-up. If relied on as a substitute it can compromise patient treatment and safety."

Elderly patients' challenges in receiving services

Discomfort in using technology and limited access to quality internet and technology

All of the elderly participants faced discomfort in using technologies and problems due to limited access to a stable internet connection: "I experience distortion in calls and signal issues, and this makes me uncomfortable and unable to share my problems with the doctor." One elderly patient with heart disease shared that he preferred telephone calls to video calls: "Primarily, the issue is sound quality and discomfort in using video calls, which are made mandatory by the doctor. Telephone calls are better and there are less connection issues too."

Time delays and long waiting periods

Many patients complained about the difficulty and time delays in scheduling telehealth appointments and having to wait for long periods of time: "The whole process from calling telehealth consultation for appointments, paying the online consultation fee, and waiting maximum 30−40 minutes for the call with the doctor is too much." A cancer survivor complained that telehealth coordination and delays caused him stress:

"I always have to wait a few days to get through to the doctor and 1–2 hours on the day of the appointment. This is very stressful and I just wish I had my own car and driver to take me." Yet another patient reported: "The doctor does not follow time schedule as per my experience. For example, if the meeting time is 3 p.m., the doctor will come online at 5 or 6 p.m."

Cost issues and difficulty in transferring payments

Though telehealth is known to be less expensive than physical consultancy, many patients complained about the cost issues and difficulty in transferring payments. A chronic liver disease patient shared: "It's like a separate cost has hit us. Now apart from the fee for in-person visits and the regular blood tests and scans, we have to pay for telehealth calls, too." Another patient shared that she was unable to make online payments and had to ask for help: "The online payment and connection issues are daunting and troublesome. I have to ask my daughter for help, which I don't like."

Difficulty in communicating and dependence on others, which compromises confidentiality

Patients shared that they faced difficulties in communicating with providers in teleclinics, and due to this, they were highly dependent on others for help during the video call. A patient described that: "I cannot explain myself very well and the doctor cannot comprehend what I am saying... So either my daughter or son talk on my behalf." A breast cancer patient shared that the lack of confidentiality prevented her from sharing all her symptoms and problems with the doctor: "One of my children or a relative has to help me during the video call and I cannot discuss all my problems with the doctor."

Little time for meeting with provider and inability to obtain comprehensive information

Other patients shared that during the teleclinic there was very little time to convey information and conduct a comprehensive meeting with the provider, and they felt stressed during the video call: "The call time is approximately 3–5 minutes, which is not sufficient for all my health-related inquiries. This gives me a lot of stress and I feel the meeting is not beneficial for me or my recovery plan." Patients with multimorbidity who needed to share the diagnosis, care plan, and medication prescribed by other specialists they were consulting also faced problems: "I have several health issues and related questions. Sometimes I need my surgeon and sometimes the physician. I have asked for group calls with all my doctors, so we can discuss the treatment plan in one go, but there has been no response about this."

Waste of time and money, as have to follow up with a physical visit

Some patients concluded that telehealth was a waste of time and money, as they had to follow up with physical visits anyway. A patient with chronic liver disease stated: "I have had a bad experience with teleclinics... Whenever I ask the doctor or his coordinator for a prescription for IV fluids, they refer me to the emergency department or send me a prescription with multivitamin syrup and a syrup for jaundice. If the teleclinic is only to refer the patient to the emergency or another doctor, then what is the point even? In the end it's a waste of time and money."

Telehealth as an isolated intervention does not solve the problem

Patients agreed that telehealth as a stand-alone service was unable to benefit them holistically for their health and well-being. Elderly patients in Pakistan suffered from multiple social, environmental, and economic issues, which impacted their uptake and satisfaction with telehealth. One patient living in a home for the elderly commented: "When my grandson visits me—which is once every few months—he schedules my teleclinic meeting with the doctor. It is like a crumb offered to a starving man. The consultant advises me multivitamins, physical exercise, and [a] visit for tests. Who is going to help with this? We [old-age residents] are restricted to our room most of the day and there is no money or transport for vitamins or health visits. Instead, my medicine would be if my grandson buys me a phone like his [smartphone] and talks to me every day."

Another elderly patient, who was a retired government employee, commented on low pension allowance and the nutritional problems of elderly patients: "Telehealth is wonderful, if it would be coupled with other more important support. My pension is only PKR 30,000 per month [USD 101.69] and not enough for the diet and medicines recommended by the doctor. Our parents lived longer because food was cheaper. We cannot afford to eat vegetables, fruit, and meat nowadays. Can telehealth transfer us funds as well for what the doctor is prescribing us?"

The way forward for sustainable telehealth for elderly patients

Pakistan must move forward to expand telehealth services without creating new inequalities for their vulnerable elderly population or what is known as "intervention-generated inequality" (Haimi, 2023). This section of the chapter discusses three bodies which must work in partnership for improvements to support optimal telehealth services for the elderly, namely the health sector, the education sector and the federal government.

Health sector

Pakistan is one of the three countries in South Asia which has great demand for telehealth services; however, the health sector is crippled by limited resources and training, low budget allocation, and an absence of the technological infrastructure to support upscaling telehealth (Eslami Jahromi & Ayatollahi, 2023). Furthermore, there is little clarity about how telehealth is to be integrated effectively into the existing model. We recommend that telehealth services for the elderly must have the following features: (1) a hybrid model and multidisciplinary online services, (2) public health sector services and screening of the elderly for telehealth services, and (3) mandatory and consistent regulation and training for providers.

Maintaining a hybrid model and multidisciplinary online services

A hybrid model of healthcare is recommended, with in-person and online health services (Chen et al., 2022). Other scholars have also argued that telehealth should be used in Pakistan for emergency situations and to provide short-term health services, but not be cut off from in-person care (Klippel, 2023). A hybrid model approach to healthcare for the elderly must include regular physical check-ups and lab tests, along with multidisciplinary telehealth services. In addition, the multidisciplinary or integrated online services may include group online calls with a multidisciplinary team of consultants to support multimorbidity patients (Kunkler et al., 2007), mandatory online sessions for screening and managing mental health issues (Elbaz et al., 2021), and group therapy calls with other patients for improved solidarity and support (Sheperis & Smith, 2021).

Other research has highlighted that once basic and integrated telehealth services based on consultancy become efficient, the elderly can also gain in the long run from advanced services such as telepathology, teledermatology, telenursing, and even telesurgery (Khemapech et al., 2019). Elders also need to be supported with regular home visits by providers and ambulatory services for pick-up and drop-off. High-risk patients must be provided support for weekly monitoring of their vital signs in the form of in-person provider visits for physical examinations and updating care plans. Integrated telehealth monitoring must also be introduced to supervise elderly patient support through combined efforts of physicians, nurses, and further care providers (Gellis et al., 2014).

Public health sector services and screening the elderly for telehealth services

Major complaints by elders are that they have no choice but to opt for telehealth due to the distance between tertiary centers and testing centers around the country. Thus, there are issues of discomfort in using telehealth due to low digital literacy, but also the issue of Pakistan not having adequate primary healthcare support for the elderly (Naz et al., 2021). Though Pakistan has a primary healthcare set-up, with local Basic Health Units (BHUs), the services are limited to family planning and reproductive health services (Rizvi Jafree et al., 2022b). We need urgent expansion of primary health services to cater for elderly patients and support in transporting them to tertiary centers for consultancy and testing. The current cadre of community health workers, known as Lady Health Workers (LHWs), who visit families at their doorsteps, can screen elders in the community for telehealth services and also help in developing a much-needed database of health problems facing the elderly. The advantage of screening through the primary sector is also that elderly patients diagnosed with functional limitations or complete physical immobility, in the same way as paralyzed patients, could be supported by primary care providers through doorstep visits for assistance with telehealth services (Kim & Ang, 2023). As the existing LHWs face immense problems of role burden and staffing shortages (Jafree et al., 2023), we also recommend that a separate workforce be hired and deployed to support primary health services for the elderly, such as health social protection officers (Jafree, 2023).

Mandatory and consistent regulation and training of providers

Elders are not without complaints related to healthcare practitioners providing online services and staff coordinators of telehealth. Wastage of time in waiting for online meetings, inability to book appointments on time, and lack of coordination with parallel providers are issues that they face. Elderly patients also indicated that the lack of online time or excess waiting time prevented them from being satisfied with their consultancy and caused them immense stress. Elderly people complain that healthcare providers not support them with sufficient information and guidance for recovery to health. There is thus a need for better staffing and coordination to deliver timely online services and satisfy the needs of elderly patients. Regulation and licensing of providers and coordinators must be achieved through regulatory bodies monitoring online services in a random manner and linking promotion and license renewal to patient satisfaction surveys. Healthcare providers and the staff coordinators providing services must be trained for online services and patient satisfaction. The training elements should include behavioral telehealth skills development, cultural competency, and ethics in practice (Gifford et al., 2012). The online medical curriculum must also include modules related to moral precepts for sufficient online consultancy time, honesty, and adequate treatment guidance with follow-up procedures (Fleming et al., 2009).

Related to ethics and privacy are also the needs of healthcare providers. Not only do public sector healthcare providers need to be compensated for telehealth consultancy to ensure job commitment, but burnout needs to be managed prudently by ensuring providers' personal contact details are not shared with clients (Barayev et al., 2021) and that they are remunerated adequately for any additional services provided to the patient (Li et al., 2019). Furthermore, to address issues regarding the lack of follow-up by clients receiving telehealth consultancy, adequate staffing of telehealth coordinators needs to be maintained. Staff officers for telehealth must go beyond just coordinating the video call by also effectively liaising with other healthcare staff and providing services for follow-up consultancy, in-person visits, and clinical tests (Ellimoottil et al., 2018).

Education sector

Pakistan's Federal Ministry and Provincial Ministries for Education and the National Literacy Program all have goals to improve adult literacy (Amir et al., 2020). Additionally, many nongovernmental organizations are committed to adult literacy programs and community-level interventions for awareness (Kalim & Bibi, 2022). These state bodies must work together to: (1) improve digital literacy in aging populations and (2) support literacy at the community level for the family members and care providers of the elderly.

Digital literacy in aging populations

Elderly patients use telehealth in Pakistan primarily due to provider preference, transport issues or the physical distance to providers or health centers—and not because they would choose telehealth over physical meetings with the healthcare provider. If telehealth is to thrive in Pakistan as part of a hybrid health service initiative, there need to be concrete interventions to improve elderly trust and confidence in the service. Elderly patients in the country prefer telephone calls to video calls, as they cannot manage video calls as easily and are more comfortable talking on the phone with their cameras off. At the same time, elderly patients also realize that a telephone call is not sufficient for diagnosis. There is thus a need for improvement in digital literacy and comfort-building sessions for video meetings (Rizvi Jafree et al., 2023b).

Literacy sessions need to be coupled with awareness about the benefits and limitations of telehealth and to share selection criteria with aging patients for when telehealth is acceptable. This will support the uptake, trust, and sustainability of telehealth services. Community-based literacy and awareness for elders may be achieved through community health workers (La Rose & Detlor, 2021) or voluntary efforts on the part of family, friends, and neighbors (Godfrey & Johnson, 2009). This requires strong collaboration and commitment by local governing bodies and union councils. Intergenerational learning programmes in the community between the elderly and youth can also facilitate digital literacy in elders, which can help ease their dependency (Rizvi Jafree et al., 2023a). There has been success in involving family caregivers to assist older adults in using and becoming comfortable with telehealth services (Ye et al., 2023). Another important aspect of the literacy efforts must be education on how to maintain the technology and internet equipment at home, for example managing the router, and wireless access point, and how to coordinate monthly payments for internet renewal or cope with technical hiccups such as internet cable damage. Similarly, the elderly also need literacy for the overall operation of the telehealth platforms and the specialized terminology used for maintenance and communication during telehealth calls (Chesser et al., 2016).

Literacy of family members and care providers

Another major issue is the dependency of the elderly on children and relatives for online payments, technological access, and support during online calls. This leaves the elders uncomfortable because they must rely on others for health uptake, and it also means they are left with no privacy or confidentiality during their meetings with the healthcare provider. There is a need for family-level digital literacy to make the family unit aware of the privacy and confidentiality rights of aging members of the household. It is also true that despite digital acumen, many elderly people may still need assistance due to their type of illness. Thus, telehealth ethics must be maintained through community-level interventions to ensure family and other care providers leave elders alone and provide them with privacy, even if they are required to help in setting up the digital meeting, whilst being available to help in case of any technological hitches during the digital consultancy. Community-level awareness of digital health has also been made possible through social media and TV so that aging populations restricted to the home can also develop awareness through morning TV shows or documentaries (Choukou et al., 2022).

State interventions

The intent of using telehealth to remove barriers to accessing health for the elderly is not possible without support and investment by a country's government (Tsai et al., 2017). The problem is more acute for developing countries that do not have the requisite infrastructure or maintenance for telehealth to begin with. However, investment in telehealth infrastructure and telehealth services for the elderly has the potential long-term benefit of reducing state health costs for chronic disease care for the aging population (Kirubakaran et al., 2023). We recommend that the following steps be taken by the state to secure optimal telehealth services for the elderly: (1) developing national telehealth guidelines, (2) monitoring and evaluating services, (3) improving technological infrastructure and resources, and (4) investing in a wider subset of protective services for the elderly, which would improve the capacity for telehealth uptake.

Developing national telehealth guidelines

Regulation of the telehealth industry and private and public providers is also needed in the country to secure patient safety, ethics, and data privacy (Nittari et al., 2020). Telehealth guidelines need to be developed in Pakistan and universalized across the country. These guidelines must include information about the types of patients eligible for telehealth, informed consent, confidentiality and privacy, and maximum waiting periods for both consultancy dates and the actual video calls on the day. Findings suggest that elders in Pakistan require state-level support in terms of calls being recorded and monitored by a third party, in case of physician or consultant violation, disrespect, or disservice (Mars, 2020). There is also a need for instituting comprehensive legislative rules for the design of information systems and records of health data through telehealth, while ensuring the privacy and confidentiality of clients (Kaplan, 2020).

Important areas of legislation and regulation must include licensing and liability, interoperability, data availability, cybersecurity, and informatics infrastructure. As telehealth services are an evolving practice, the health sector and private organizations must be provided with updated guidelines for the ethical use of telehealth care, and in consideration of the social and legal issues relevant to the country (Kaplan, 2020). Furthermore, elderly users must be made sufficiently aware of informed consent, confidentiality, and possible breaches in patient privacy, which will also help to improve trust and uptake of telehealth amongst elderly groups (Eslami Jahromi & Ayatollahi, 2023).

Monitoring and evaluation

As mentioned earlier, elderly patient satisfaction surveys must be used for assessing performance and licensing telehealth providers. Regular training of providers and coordinators about the needs of elderly clients and optimal client management needs to be mandated and funded by the government. Stakeholders in Pakistan—including the state health sector, private and public digital health sectors, IT and Wi-Fi companies, health regulatory bodies, and health education and training bodies—need to coordinate consistently and closely to secure patient safety for elders. This will be possible by constituting a federal-level committee for telehealth regulation in the country, which has branch committees at the provincial level for efficient coordination across the large population and remote areas. Other scientific research also recommends that the sustainability of telehealth is only possible through regular collaboration between policymakers, academicians, and private-sector organizations, who need to effectively come together to assess, evaluate, and modify telehealth services in evolving regional circumstances (Kvedar et al., 2014).

Improved technological infrastructure and resources

The larger issue of course has little to do with providers or elderly patients. It is promising that the Ministry of Information Technology and Telecommunication in Pakistan has promised to ensure the provision of affordable, reliable and consistent delivery of Internet access to all citizens in the country (Rizwan, 2023). However, targets have not yet been met, and there are no government-sponsored schemes for elderly access to computer equipment and smartphones. Previous government efforts have shown some success in the laptop schemes for youth and university students (Khan et al., 2019). A similar scheme needs to be launched for smartphone provision, free Wi-Fi access, and digital literacy to help secure health access for elderly people across the nation. Critical and urgent investment is needed for digital infrastructure and maintenance of this infrastructure in terms of continuous and quality services, financial sustainability, and systematic collaboration between care centers at all levels (Thanakijsombat et al., 2022).

In developing countries, it has been concluded that cost-friendly and simple media should be used for elderly groups, such as telephone calls or video calls using the WhatsApp application (Hoffer-Hawlik et al., 2020). WhatsApp has the benefits of including a variety of easy communication media for the elderly, such as texts, video calls, and transfer of media files and prescription or lab tests as attachments. Other research confirms that when the state intervenes with the supply of technology to households, the transition to telehealth is secured without any gaps or inequalities based on differences in ethnicities, regions, and socio-economic groups (Connolly et al., 2020). This is important for Pakistan, as it is a country characterized by ethnic and religious pluralism and large rural populations (Jamil, 2020).

There are newly emerging private telehealth companies in Pakistan (Jabeen & Rabbani, 2023), which are investing in digital resources and facilitating communication between elderly patients and medical professionals through video chats and calls. Tax concessions and subsidies to support these private firms will help build a public-private partnership for telehealth access for the elderly. It is also recommended that a National Telehealth Advisory Council should be created, which would help with information-sharing and best practices for improved services and upscale (Kearly et al., 2020). Furthermore, a separate and coordinated emergency telehealth line needs to be established to provide remote elderly clients with support.

Wider subset of protective services for the elderly

Telehealth services must be considered a subset of the wider protective needs for maintaining the health and well-being of the aging population in Pakistan (Rizvi Jafree, 2023). The future success of telehealth will depend on key social policy efforts to support the aging population facing social and environmental problems related to poverty, food insecurity, mobility, and social isolation (Bloom et al., 2012). Community-level programs delivered through social protection officers can be helpful in identifying the elderly population groups in need of protective services. The public and private sectors must partner up to develop support to keep the elderly active and healthy, which would improve their commitment to seeking digital health services, through intergenerational learning programs, community programs for elderly activities, and part-time consultancy or voluntary work programs for the elderly (Murayama et al., 2015; Wang et al., 2020; Wu et al., 2005).

Cost is a major concern for elderly patients, who consider telehealth expenses to be an added financial burden with limited benefits. At the moment in Pakistan, there is little consideration for integrating telehealth costs into state health coverage schemes or private health insurance (Ahmad et al., 2021). This needs to change, and the expense of telehealth needs to be heavily subsidized or included in insurance plans for elderly patients. Other studies from the developing world have shown success in providing reimbursement to patients for using telehealth (Fesler et al., 2020).

Conclusion

Despite the challenges, telehealth is here to stay and is an integral health service for patients in the event of difficulties with mobility, distance, pandemics, natural disasters, and emergencies. In fact, the high infectious disease burden in countries like Pakistan makes the necessity of integrating telehealth services even more vital to support elderly and vulnerable patients. However, strong collaboration is needed in Pakistan to ensure that telehealth services achieve optimal results for elderly patients' health management. Firstly, elders need to be screened for eligibility to receive telehealth services, and the digital infrastructure needs to be adequate for uninterrupted access by elders, especially in remote areas. Telehealth must be upscaled in the country, with strict service and ethical guidelines developed by all stakeholders to ensure optimal elderly patient outcomes and quality of care for an aging population with diverse and multiple health issues. Secondly, community health workers need to support elders with digital literacy and in-person consultancy at local BHUs. Thirdly, the telehealth services supplied by providers and support staff need to be improved through training, better staffing, and responsiveness based on elderly patient satisfaction surveys. Fourthly, we recommend telehealth services forming part of a hybrid service model and acting as an enabling tool within the wider healthcare model, to be partnered with in-person consultancy and including mandatory parallel online services and integrated telehealth services, especially for the management of multimorbidity and mental health.

Finally, none of the above is possible without the major commitment and financial investment by the state, which includes investment in telehealth and a comprehensive social protection net for the aging population. Direct telehealth investment must include expenditure for digital infrastructure and adequate maintenance, subsidization and financing solutions for telehealth, training, and staffing for providers, and expanding the services of BHUs to offer comprehensive geriatric care. Indirect investment in social policy for the aging population would ensure that telehealth services are effective. These policy initiatives must target financial relief, capacity building, universal health coverage, universal pension coverage in line with inflation rates, free or subsidized public transport and dedicated ambulance transport for elderly patients, food subsidization, and delivery of food and medicines to the doorstep. Urgent efforts are also needed to support the issues of loneliness and isolation facing elders so that they can become empowered and active agents in seeking recovery of their health.

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CHAPTER 10

Digital health in ASEAN an exploratory analysis

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Introduction

The objective of digital health is to enhance efficiency, reduce costs, and elevate the quality of medical care offered to patients (Kadhim et al., 2020). Instances of such technology encompass electronic health records (EHRs) utilized for centralized management of patient data, telehealth facilitating remote patient consultations and monitoring, mobile health (mHealth) catering to health-related mobile applications, and wearable devices designed for continuous healthcare monitoring (Anshari & Almunawar, 2016). The incorporation of these technological innovations into digital healthcare holds the potential to enhance health outcomes, patient engagement, operational efficiency gains, service accessibility, and insights derived from data analysis. However, challenges relating to data security, uneven technology access, complex regulations, and ensuring the quality of digital health services need consideration as the healthcare landscape evolves rapidly (Hordern, 2016).

In addition, the COVID-19 pandemic has pushed the boundaries of digital health even further (El Otmani Dehbi et al., 2021). Prepandemic, substantial advancements were already made in digital health, encompassing the adoption of EHRs to elevate care quality and efficiency, a surge in telehealth for remote medical consultations, the development of mHealth applications to facilitate health tracking and chronic disease management, and the introduction of wearable devices to monitor health metrics (Taha et al., 2022). Following the pandemic, there has been an exponential rise in the utilization of digital health technology. mHealth has emerged as a tool allowing patients to monitor symptoms, self-manage, and maintain communication with healthcare providers in cases where physical clinic attendance is not feasible (Adebayo et al., 2020; Anshari & Almunawar, 2015; Anshari et al., 2013). The integration of wearable devices into healthcare is driving significant transformations in the delivery and management of healthcare by enabling the monitoring of chronic illnesses and tracking the transmission of viruses.

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The Association of Southeast Asian Nations (ASEAN), composed of ten countries in Southeast Asia and a population exceeding 650 million, is emerging as a vibrant hub for digital health technologies (Liang et al., 2023). The evolution of digital health within the ASEAN region has been marked by swift progress, with its momentum further accelerated by the COVID-19 pandemic (Haqqi & Murdani, 2023). This global health pandemic prompted ASEAN member countries to capitalize on digital health solutions, thereby amplifying the enhancement of healthcare delivery. Significant trends shaping ASEAN's digital health landscape encompass the increasing embrace of mHealth for streamlined management of patient information, the surging popularity of telehealth for remote consultations and health management, including chronic conditions, and the integration of wearable devices to monitor health data (Jandoo, 2020). The region occupies a pivotal role in the global digital health market, primarily due to its diverse population offering a fertile ground for experimenting with varied digital health technologies, its burgeoning economy providing a substantial market, and its healthcare challenges, notably those arising from COVID-19 and chronic diseases, finding potential solutions through these digital innovations (Nouri et al., 2020).

In the evolving landscape of healthcare, digital technologies are becoming increasingly pivotal, transcending geographical boundaries. As ASEAN navigates the complex domain of digital health, it is crucial to understand its development, challenges, and future prospects. The Global Digital Health Monitor (GDHM) is a useful instrument for assessing the development of digital health in ASEAN countries. Its comprehensive framework provides a systematic prism through which to evaluate several facets, such as leadership and governance, infrastructure, and services (Llamzon et al., 2020). By using this comprehensive approach, interested parties may get a sophisticated comprehension of the digital health ecosystem and make educated decisions and precise actions (Almunawar et al., 2023b) that will have the most impact. This chapter's aim is to provide an analysis of digital health adoption in ASEAN countries, including a discussion of the region's present condition and trends, the possibilities and threats it faces, and the effects that these technologies have on healthcare delivery and patient participation. To better understand how digital healthcare can transform healthcare delivery in the ASEAN region, it is important to provide insights into the wide variety of digital health technologies used in the region, investigate drivers and barriers to adoption, tackle regulatory and privacy concerns, and provide recommendations for effective implementation and future trends (Mohd Arif & Choo Ta, 2022).

Literature review

Digital health is a broad term that refers to the use of digital technology to promote health and well-being as well as to assist in the delivery and management of healthcare services (Anshari et al., 2023b; FDA, 2020). Examples of digital health applications include mHealth, telemedicine, wearable devices, health information systems, and personalized medicine (HIMSS, 2020). With the advent of cutting-edge breakthroughs like AI, big data, the cloud, and blockchain, digital health has progressed and matured over time (BMCDigitalHealth, 2023). Accessible, efficient, effective, and individually tailored solutions to a wide range of health problems are just some of the ways in which digital health has the potential to revolutionize healthcare.

The ASEAN digital healthcare policy refers to initiatives that attempt to increase the use of digital health services throughout the region. Telemedicine, EHRs, mHealth applications, and health information systems are all examples of how information and communication technology (ICT) is being used to improve healthcare delivery (Anshari, 2019). There is hope that the integration of digital health services may improve healthcare delivery across the ASEAN. Considering the COVID-19 epidemic and the rising needs of the elderly and middle class, this possibility is all the more pressing.

Digital health — ASEAN Digital Master Plan 2025

The ASEAN Digital Master Plan 2025 is a strategic road map that will guide digital collaboration and integration across the ASEAN region over the next 5 years (Nasution, 2021). With the use of safe and innovative digital services, technology, and ecosystems, ASEAN hopes to become a global leader in the digital community and economic powerhouse (ASEAN, 2021). One of the foremost priorities within this plan centers on elevating digital health throughout ASEAN. This involves harnessing ICT to deliver healthcare services, encompassing telemedicine, EHRs, mHealth applications, and health information systems. The potential of digital health to enhance healthcare accessibility, affordability, and quality gains heightened significance amidst the challenges posed by the COVID-19 pandemic and the burgeoning demands from both the aging population and middle-class segment (ASEAN, 2020).

To actualize this critical priority, the plan outlines a series of actionable steps for ASEAN Member States (AMS) to undertake, including; *firstly*, *crafting national digital health strategies and policies that align with regional and global frameworks* (ASEAN, 2021). Devising national digital health strategies and policies that harmoniously align with both regional and global frameworks is a paramount step outlined by the ASEAN Digital Master Plan 2025. This involves meticulously formulating comprehensive roadmaps that not only cater to the unique healthcare landscape of each member state but also seamlessly integrate with broader regional and worldwide agendas. By tailoring these strategies to cater to local healthcare challenges while adhering to overarching international standards, ASEAN countries can ensure the cohesiveness of their digital health efforts on a global scale (de Melo & Papageorgiou, 2021). This synergy in strategy not only facilitates streamlined information exchange and collaboration but also strengthens the foundation for the growth and sustainability of digital health initiatives across borders.

Secondly, *advancing interoperability and standardization of regulations and standards for digital health services and data across AMS* (ASEAN, 2021). Promoting the advancement of interoperability and standardization of regulations and standards for digital health services and data across AMS emerges as a pivotal directive within the ASEAN Digital Master Plan 2025. This imperative task entails fostering a unified framework that transcends national boundaries, ensuring that digital health systems and data seamlessly communicate and interact among diverse member nations (Chen et al., 2023). By establishing common norms and protocols, AMS can dismantle potential barriers that might impede the exchange of vital healthcare information, thereby facilitating more efficient cross-border collaborations. This effort also encompasses the formulation of consistent regulations to govern the security, privacy, and ethical utilization of digital health data, further bolstering the trust and reliability of these services. Ultimately, through the harmonization of these vital aspects, AMS not only enhance the efficacy and accessibility of their digital health initiatives but also lays a resilient foundation for the region's collective healthcare progress (Anshari et al., 2023a).

Third, augmenting digital health literacy and competencies among healthcare providers and consumers (ASEAN, 2021). Elevating digital health literacy and competencies among both healthcare providers and consumers is a paramount objective outlined within the ASEAN Digital Master Plan 2025. This multifaceted endeavor entails not only equipping healthcare professionals with the requisite knowledge and skills to navigate and leverage digital tools effectively but also empowering patients to actively participate in their healthcare journey through technological means. For healthcare providers, this entails comprehensive training programs that encompass a spectrum of digital health applications, ranging from electronic medical records management to telemedicine practices. These initiatives not only ensure that medical practitioners remain up-to-date with the latest technological advancements but also instill the ability to harness these innovations to provide more personalized, efficient, and patient-centric care. On the consumer front, enhancing digital health literacy involves disseminating user-friendly educational resources that elucidate the benefits and functionalities of digital health platforms. By fostering a deeper understanding of digital health services among the general public, individuals can make informed decisions about their health and seamlessly engage with telehealth consultations, health monitoring applications, and other digital resources. Through these concerted efforts, AMS can effectively bridge the digital divide in healthcare, cultivating a healthcare ecosystem where both providers and recipients are equipped with the proficiency needed to maximize the potential of digital innovations, resulting in improved healthcare outcomes and patient experiences (Ordoñez de Pablos, 2023).

Forth, *reinforcing regional collaboration and coordination pertaining to digital health initiatives, encompassing the exchange of best practices, data, and resources* (ASEAN, 2021). Strengthening regional collaboration and coordination in relation to digital health initiatives represents a cornerstone principle articulated within the ASEAN Digital Master Plan 2025. This cornerstone envisions a dynamic network where AMS collaboratively pool their expertise, experiences, and resources to foster a collective momentum towards enhanced healthcare delivery through digital means. Within this framework, a robust exchange of best practices emerges as a pivotal avenue, allowing nations to learn from each other's successes and challenges. By sharing insights on effective strategies, innovative approaches, and lessons learned, member states can accelerate the implementation of digital health solutions, minimizing redundancies and amplifying positive outcomes. Additionally, the exchange of data emerges as a potent catalyst for informed decision-making and policy formulation. Collaborative data-sharing mechanisms enable countries to gain a comprehensive understanding of regional health trends, allowing for timely interventions and targeted responses to emerging health challenges. This data-driven approach enhances the accuracy of public health assessments and empowers policymakers to make evidence-based choices (ASEAN, 2021).

Finally, *capitalizing on digital health innovations and solutions to effectively address healthcare challenges and disparities within ASEAN* (Xinhua, 2021). Harnessing the transformative potential of digital health innovations and solutions to proactively tackle the spectrum of healthcare challenges and disparities prevalent within the ASEAN region stands as a key tenet within the ASEAN Digital Master Plan 2025. This strategic imperative envisions a landscape where cutting-edge technological advancements are strategically integrated to bridge existing healthcare gaps, ultimately fostering equitable access to quality healthcare for all segments of the population. Embracing digital health innovations offers a strategic advantage in devising tailored interventions that cater to the region's unique healthcare landscape. Through predictive analytics, artificial intelligence, and data-driven insights, member states can anticipate health trends, allocate resources effectively, and design targeted interventions that directly address pressing health concerns (Almunawar et al., 2023a). For instance, personalized health management tools can empower individuals to take proactive steps towards preventing chronic diseases, thus curbing the burden of noncommunicable illnesses. Furthermore, leveraging telemedicine and remote healthcare solutions can transcend geographical barriers, offering healthcare services to remote and underserved areas. This bridging of geographic divides ensures that vulnerable populations gain access to medical expertise, diagnostics, and consultations that were previously out of reach, thereby narrowing healthcare disparities. Digital health solutions also empower member states to respond swiftly to emerging health crises, as evidenced during the COVID-19 pandemic. Rapid deployment of telehealth services, remote patient monitoring, and digital contact tracing bolstered the region's resilience in the face of unprecedented challenges. By capitalizing on these digital health innovations, ASEAN can not only effectively address immediate healthcare challenges but also work toward long-term sustainable solutions that promote health equity, strengthen healthcare systems, and contribute to the overall well-being of its diverse population. Through the collective pursuit of these measures, ASEAN envisions the cultivation of a more robust and comprehensive health system, one capable of offering inclusive benefits to all its constituents (ASEAN, 2021).

ASEAN healthcare spending

Despite a 250% surge in healthcare spending throughout the ASEAN region, key indicators like life expectancy and the Universal Health Coverage (UHC) index scores remain lower across the region compared to numerous developed nations (Dolic & Moarcasr, 2019). Over the next two decades, a remarkable surge in healthcare demand is projected, wherein all ASEAN nations are expected to predominantly consist of aging populations, while approximately 9 million individuals continue to succumb to lifestyle-related diseases annually. Additionally, most of the major ASEAN countries, including Malaysia, Singapore, Indonesia, Vietnam, the Philippines, and Thailand, are anticipated to allocate less than 5% of their GDP to healthcare. Concurrently, the UHC Index scores are expected to hover around 70 out of 100 (Strausz, 2018). The UHC Index signifies the accessibility of promotive, preventive, curative, rehabilitative, and palliative health services of adequate quality, without causing financial distress. In essence, it underscores equitable health service access, wherein everyone needing the services should access them without financial constraints (Robock, 2014).

For example, Indonesia's public health service inequities persist as a social problem requiring continuous comprehensive evaluations for viable solutions. Although the government offers public health insurance, individuals from low-income families still encounter difficulties in accessing quality health treatments. Regrettably, insurance coverage is insufficient for all health issues and illnesses, leaving them responsible for expensive treatment costs. Thus, the persistently low UHC index scores across ASEAN regions emphasize the necessity for the countries to explore alternative healthcare financing strategies. The increasing adoption of crowdfunding platforms for healthcare costs, observed in low, middle, and high-income countries including ASEAN nations, presents a novel funding approach to enhance healthcare financing within the region.

Furthermore, in 2019, less than 10% of healthcare budgets in ASEAN regions like Malaysia, Singapore, Indonesia, Vietnam, the Philippines, and Thailand were allocated to disease prevention programs, as compared to developed countries (Ordanini et al., 2012). The prevalent healthcare service purchasing model prioritizes volume-based activities, possibly undervaluing innovation and healthcare infrastructure enhancement in the selected ASEAN countries. Determining appropriate healthcare spending for a nation is challenging, as the amount required differs significantly based on population health challenges. Countries grappling with malnutrition, endemic malaria, and an HIV epidemic would have distinct spending needs compared to those with limited infectious diseases and a high prevalence of chronic conditions (Hemer, 2014).

The insufficient allocation of funds to the healthcare sector also suggests a potential shortage of human capital within the system. Consequently, as certain ASEAN countries face unreliable infrastructure and technology, the concept of crowdfunding has gained traction. This approach empowers individuals to seek medical treatment in developed countries known for their superior healthcare infrastructure and innovation. This is achieved by gathering small contributions from a large number of people, typically facilitated through the Internet (Dragojlovic & Lynd, 2014). Moreover, the limited share of the budget directed towards the healthcare industry implies that developing countries might face financial crises, resulting in reduced innovation and development within the healthcare sector (Young & Scheinberg, 2017). A prime example is Singapore, currently grappling with medical research funding crisis, leading to lab downsizing, project closures, early researcher retirements, and discouragement of young scientists from pursuing research careers (Kozinets & Hemetsberger, 2019). Consequently, crowdfunding has emerged as a viable alternative for healthcare funding, offering economic benefits by expanding market participation, shedding light on neglected health issues, enhancing funding access, and fostering project accountability and social engagement.

Global Digital Health Monitor

The research takes an exploratory approach, drawing insights from the available information within the framework of the GDHM. The GDHM serves as an interactive online platform that strives to monitor, track, and assess the conducive factors contributing to the advancement of digital health worldwide. This platform utilizes seven primary indicator categories to measure advancements across diverse domains, including Leadership & Governance, Strategy & Investment, Legislation, Policy, & Compliance, Workforce, Standards & Interoperability, Infrastructure, and Services & Applications (Fig. 10.1). It provides a holistic view of the global digital health landscape, allowing for informed assessments of the status and developments in the digital health arena.

The GDHM consists of several fundamental categories that collectively illuminate the digital health landscape. Evaluating global, regional, and national levels of leadership, vision, and coordination in digital health is the focus of the GDHM's Leadership and Governance category. The availability and effectiveness of governance mechanisms, such as steering committees, advisory boards, or technical working groups, that monitor and direct the planning and implementation of digital health initiatives are also evaluated here (WHO, 2020). For example, a national digital health vision statement, a national digital health steering committee, a national digital health focal point,

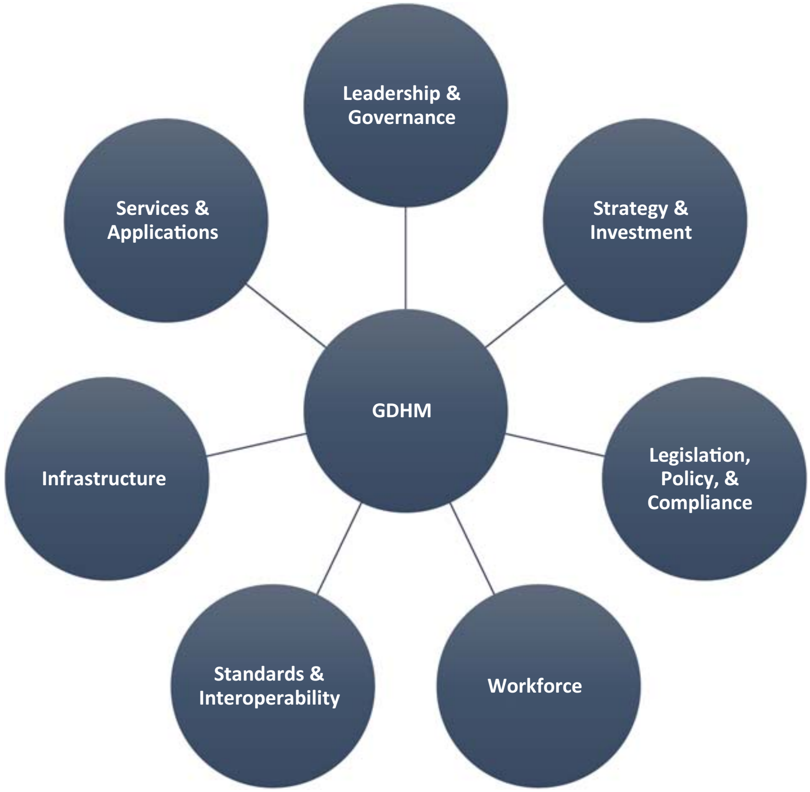

Figure 10.1 Components of Global Digital Health Monitor.

participation in a regional or global digital health network, and involvement in global digital health initiatives are all part of the leadership and governance assessment (Marcelo et al., 2018).

The Plan and Investment section of the GDHM is very important since it examines the global, regional, and national levels of a digital health plan that is clearly defined, supported by evidence, and adequately financed. This category also measures the availability and quality of investment mechanisms, including funding sources, business models, or partnerships, that offer support for the development and implementation of digital health initiatives (WHO, 2020). The evaluation of Strategy & Investment encompasses a range of subindicators, including the existence of a national digital health strategy, alignment of the strategy with the national health framework, the presence of a national digital health investment plan and budget, establishment of a national digital health innovation fund, existence of a regional or global digital health strategy.

Another critical facet under the purview of the GDHM is Legislation, Policy, & Compliance, encompassing the assessment of a comprehensive, harmonized, and all-encompassing legal and policy framework for digital health across global, regional, and national realms. This category also evaluates the availability and quality of compliance mechanisms, including regulations, standards, or guidelines, ensuring the safety, quality, privacy, and security of digital health initiatives1. The evaluation of Legislation, Policy, & Compliance encompasses an array of subindicators, including the presence of national digital health legislation, national digital health policy, and national digital health compliance mechanisms (Digitalhealthmonitor, 2023).

Workforce stands as another vital category within the GDHM, embracing the assessment of a sufficiently staffed, skilled, and motivated healthcare workforce adept in the use of digital health solutions across global, regional, and national tiers (Pote et al., 2021). This category also evaluates the availability and quality of educational and training mechanisms, including curricula, courses, or certifications, designed to augment the knowledge and competencies of the healthcare workforce in the domain of digital health. The assessment of the Workforce incorporates a variety of subindicators, such as the presence of a national digital health workforce assessment, a national digital health workforce strategy, a national digital health workforce registry, and the availability of national digital health education and training mechanisms (Nazeha et al., 2020).

Standards & Interoperability constitute another pivotal category within the GDHM, encompassing the assessment of well-defined, universally accepted standards and specifications that facilitate the seamless and secure exchange of health data among users, healthcare providers, health system managers, and health data services on global, regional, and national scales. This category also evaluates the availability and quality of implementation mechanisms, including testing, certification, or accreditation, aimed at ensuring the compliance and interoperability of digital health solutions. The evaluation of Standards & Interoperability incorporates a range of subindicators, such as the presence of a national digital health standards framework, a national digital health standards adoption mechanism, and a national digital health standards implementation mechanism (Bourquard et al., 2014).

Infrastructure constitutes another crucial category within the GDHM, encompassing the assessment of a dependable, secure, and scalable physical and technological framework that facilitates the development, implementation, and utilization of digital health solutions across global, regional, and national tiers (WHO, 2020). This category also evaluates the availability and quality of infrastructure components, including hardware, software, networks, platforms, or cloud services, that enable the effective delivery and administration of digital health services. The assessment of Infrastructure incorporates various subindicators, such as the presence of a national digital health infrastructure assessment, a national digital health infrastructure strategy, a national digital health infrastructure registry, and the availability of a national digital health infrastructure management mechanism (Hui et al., 2022).

Lastly, Services & Applications within the GDHM evaluates the presence of impactful, efficient, and impartial digital health services and applications that effectively cater to the health needs and priorities of populations across the global, regional, and national spectrum. Furthermore, this category assesses the quality and availability of mechanisms for managing and delivering services, encompassing design, development, deployment, monitoring, evaluation, and scalability, which collectively ensure the pertinence, quality, and resonance of digital health solutions (Alami et al., 2017). This assessment involves a range of subindicators, including the presence of a national digital health services and applications assessment, a national digital health services and applications strategy, a national digital health services and applications registry, and the availability of a national digital health services and applications management mechanism.

Methodology

This research adopts a qualitative methodology, focusing on secondary data analysis, particularly drawing from the comprehensive dataset of the GDHM. Secondary data analysis is chosen as it allows for an in-depth exploration of the digital health landscape across ASEAN member countries through an established framework. The GDHM dataset offers a rich source of information encompassing various key indicator categories, such as Leadership & Governance, Strategy & Investment, Legislation, Policy, & Compliance, Workforce, Standards & Interoperability, Infrastructure, and Services & Applications. By systematically analyzing this existing dataset, this approach aims to uncover patterns, trends, and insights that shed light on the digital health readiness, progress, and challenges within the ASEAN region, thereby contributing to a comprehensive understanding of the subject matter.

Analysis and discussion

The research analysis employs an exploratory methodology, deriving insights from the accessible data within the context of the GDHM. The GDHM functions as an interactive online platform with the aim of monitoring, tracing, and evaluating the factors that foster the progress of digital health on a global scale.

Brunei Darussalam

Brunei stands among the nations that have undergone an assessment of their conducive environment for digital health advancement. The assessment process employs a set of seven key indicator categories, namely Leadership & Governance, Strategy & Investment, Legislation, Policy, & Compliance, Workforce, Standards & Interoperability, Infrastructure, and Services & Applications, to effectively gauge and track progress.

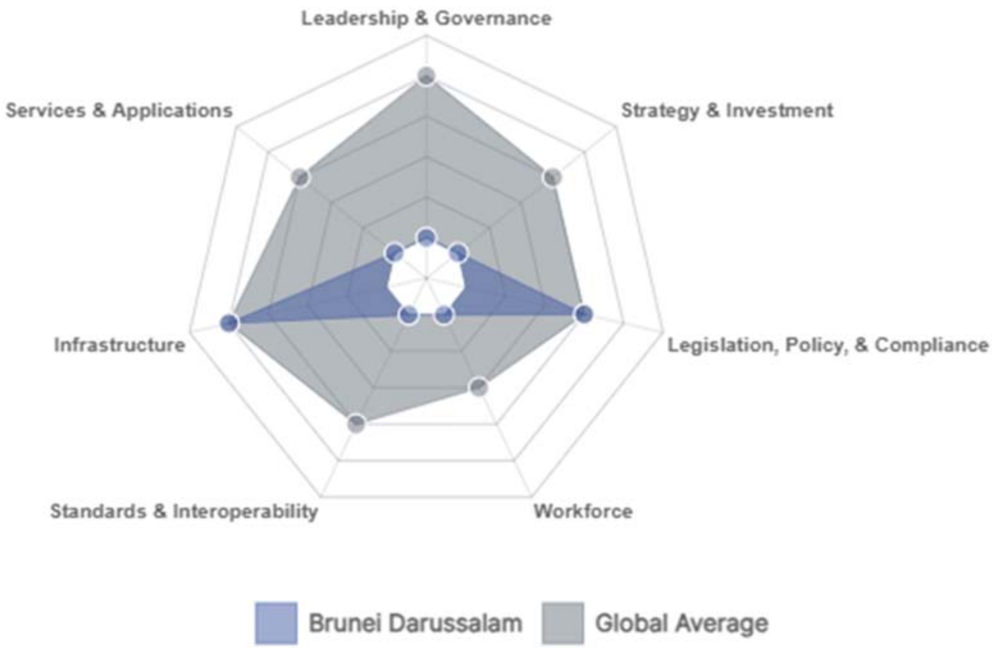

Figure 10.2 Brunei's Digital Health Phase Overview. *From Global Digital Health Monitor (2023).*

Drawing from the latest data available for the year 2022, Brunei exhibited an overall indicator category score of 67.9%, surpassing the global average of 54.6%. This indicates that Brunei boasts a relatively robust and supportive framework for the development and execution of digital health initiatives (Fig. 10.2).

Brunei has demonstrated commendable strengths and achievements in the realm of digital health, showcasing its commitment to advancing healthcare through innovative technology and strategies. These include the presence of a comprehensive national digital health vision statement that aligns seamlessly with the overarching national health vision and the sustainable development goals (SDGs), ensuring a harmonious trajectory. The establishment of a robust national digital health steering committee further highlights the nation's dedication to coordinating and overseeing digital health initiatives across diverse sectors and stakeholders. Brunei's commitment to ethical and effective digital health practices is underscored by its well-structured national digital health legislation, which extensively covers critical aspects such as data protection, privacy, security, ethics, and quality.

In line with its vision, Brunei has designated a dedicated national digital health focal point to serve as a pivotal link for both national and international digital health matters, reflecting its proactive engagement with the global digital health community. The provision of a national digital health innovation fund offers financial support for innovative and scalable digital health solutions, contributing to the ongoing advancement of healthcare services. The meticulous monitoring of the digital health workforce is facilitated by a comprehensive national digital health workforce registry, ensuring its optimal distribution and availability.

Moreover, Brunei's commitment to capacity-building is evident through its comprehensive national digital health education and training mechanism, which offers diverse courses and certifications tailored to enhance the skills of the digital health workforce (Anshari et al., 2023b). The nation's commitment to interoperability and standardized practices is fortified by the presence of a well-established national digital health standards framework, aligning with global and regional standards for seamless data exchange. The robust cataloging and maintenance of the physical and technical components critical to digital health, as evidenced by the national digital health infrastructure registry, underpin the nation's efforts to provide a conducive environment for digital health development.

Adding to its accomplishments, Brunei has introduced the MOH Intelligence Hub, a forward-looking digital center focused on research and surveillance, aimed at bolstering the country's healthcare system. This comprehensive array of strengths and achievements exemplifies Brunei's dedication to advancing digital health and underscores its role as a prominent player in the global digital health landscape (Bruneian, 2022). While, BruHealth, created by the Brunei government, stands out as one of the most widely used digital health applications in the country. Originally developed to engage Brunei residents during the COVID-19 pandemic, the app serves as a comprehensive platform. It keeps residents informed about COVID-19 developments and related policies, facilitates self-assessment for monitoring health conditions, and utilizes Bluetooth and GPS tracking features to monitor the risk exposure of individuals in Brunei. Additionally, BruHealth offers various features, health knowledge hub, nearby activity trace, online visit appointment scheduling, online personal health records, and online video consultations (MOH, 2022).

Cambodia

Cambodia is one of the countries that has been assessed for its enabling environment for digital health. The monitor uses seven key indicator categories to track progress, such as Leadership & Governance, Strategy & Investment, Legislation, Policy, & Compliance, Workforce, Standards & Interoperability, Infrastructure, and Services & Applications (Fig. 10.3).

Based on the latest data from 2022, Cambodia's overall indicator score stood at 41.4%, falling below the global average of 54.6%, indicating a relatively less conducive environment for the development and implementation of digital health initiatives. Despite the challenges, Cambodia has showcased noteworthy strengths and accomplishments in the

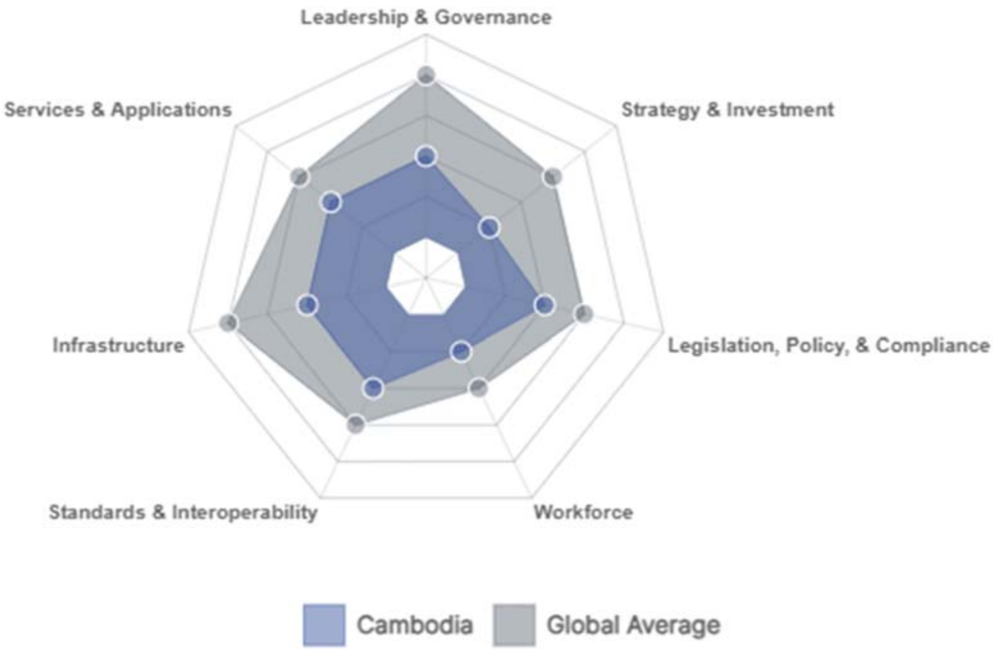

Figure 10.3 Cambodia's Digital Health Phase Overview. *From Global Digital Health Monitor (2023).*

realm of digital health, indicating its commitment to progress in the healthcare sector. A national digital health vision statement aligns cohesively with the national health vision and the SDGs, setting a clear trajectory for digital health advancement. The establishment of a comprehensive national digital health policy underscores Cambodia's dedication to addressing various dimensions of digital health, encompassing data protection, privacy, security, ethics, and quality.

Moreover, Cambodia's commitment to its digital health workforce is evident through its systematic national digital health workforce assessment, which identifies the prevailing and future needs and gaps within the digital health workforce landscape. The nation's focus on capacity-building is further demonstrated by its robust national digital health education and training mechanism, offering an array of courses and certifications tailored to enhance the skill sets of the digital health workforce. These strengths collectively contribute to Cambodia's efforts to foster a digital health ecosystem that can cater to the evolving healthcare landscape.

Additionally, Cambodia's endeavor to assess its digital health services and applications landscape is exemplified by its national digital health services and applications assessment. This evaluation gauges the availability and effectiveness of digital health solutions within the country, indicating a proactive approach to optimizing healthcare services through technological integration. Despite the challenges posed by the lower overall score, Cambodia's initiatives and achievements in digital health serve as pivotal steps towards enhancing its healthcare landscape and embracing the opportunities presented by the digital era. Several digital health apps in Cambodia include SnapRx, which seamlessly generates real-time health data from prescriptions. This app aids users in monitoring their medication adherence, receiving refill reminders, and managing potential drug interactions. Furthermore, it provides personalized health insights and recommendations based on the user's data.

Another notable app is mClinica, serving as a comprehensive healthcare ecosystem platform connecting patients with doctors, pharmacies, labs, and hospitals. Users can utilize this platform to book appointments, order medications, undergo lab tests, and access their medical records online. Additionally, mClinica offers telemedicine services and chatbot support.

Indonesia

Indonesia is one of the countries that has been assessed for its enabling environment for digital health. The monitor uses seven key indicator categories to track progress, such as Leadership & Governance, Strategy & Investment, Legislation, Policy, & Compliance, Workforce, Standards & Interoperability, Infrastructure, and Services & Applications. Based on the latest data from 2022, Indonesia scored 59.3% in the overall indicator category, which is higher than the global average of 54.6%1 (Fig. 10.4).

This indicates that Indonesia has cultivated a notably robust and supportive environment for the advancement and implementation of digital health solutions. A plethora of strengths and accomplishments in the realm of digital health illuminate Indonesia's proactive approach to harnessing the potential of technology in healthcare.

First and foremost, the presence of a clear and comprehensive national digital health vision statement, harmoniously aligned with both the national health vision and the SDGs, underscores Indonesia's commitment to a cohesive digital health strategy. Reinforcing this strategy is the well-established National Digital Health Steering Committee, playing a pivotal role in coordinating and overseeing digital health initiatives across diverse sectors and stakeholders.

Furthermore, Indonesia's commitment to a robust regulatory framework is exemplified by its comprehensive national digital health legislation, which comprehensively addresses intricate aspects of digital health, including data protection, privacy, security, ethics, and quality. This commitment extends to the establishment of a dedicated national digital health focal point, serving as a bridge between domestic and international realms of digital health collaboration.

Indonesia's commitment to strategic planning is further evidenced by the presence of a national digital health strategy, which provides a clear roadmap encompassing goals, objectives, priorities, and actions for digital health development and implementation. The

Figure 10.4 Indonesia's Digital Health Phase Overview. *From Global Digital Health Monitor (2023).*

integration of financial planning is apparent through the national digital health investment plan, effectively outlining budgetary requirements and sources essential for the realization of digital health initiatives.

The comprehensive landscape of digital health in Indonesia extends to regulatory mechanisms. The presence of a national digital health compliance mechanism highlights Indonesia's commitment to ensuring the safety, quality, privacy, and security of digital health solutions. The nation's investment in human capital is visible through its national digital health workforce assessment and strategy, addressing the dynamic needs of a skilled digital health workforce, and ensuring recruitment, retention, motivation, and performance optimization.

As a testament to Indonesia's digital health commitment, the presence of a national digital health workforce registry offers meticulous tracking and monitoring of the workforce's distribution and availability. Capacity-building is further prioritized through a comprehensive national digital health education and training mechanism, providing a range of courses and certifications tailored to nurture the expertise of the digital health workforce.

Moreover, the implementation of global and regional standards is evident in Indonesia's robust national digital health standards framework, fostering seamless data exchange and interoperability. The subsequent adoption and implementation mechanisms reflect a commitment to industry-wide adherence. Indonesia's digital health infrastructure is bolstered by a comprehensive national digital health infrastructure assessment, meticulous planning through a national digital health infrastructure strategy, and ongoing maintenance via an infrastructure management mechanism. Such efforts are directed toward ensuring the availability and quality of physical and technical components for digital health.

An assessment of digital health services and applications showcases Indonesia's strides in ensuring availability and effectiveness, while a strategic roadmap further guides the design, development, deployment, monitoring, evaluation, and scalability of impactful digital health solutions. This is complemented by a robust services and applications registry, effectively cataloging available solutions. Indonesia's accomplishments in digital health serve as a testament to its concerted efforts to revolutionize healthcare through technology, embracing a comprehensive approach across myriad dimensions of digital health. An example of a leading digital health app in Indonesia is Halodoc. This app serves as a healthcare network platform, connecting users to licensed doctors online. Users can consult with doctors through chat or calls, access health articles, and order medicines. Additionally, Halodoc offers personalized health insights and recommendations based on the user's data. With over 20 million monthly users, Halodoc is playing a crucial role in providing accessible healthcare to millions of citizens in the country.

Laos

Based on the latest data from 2022, Lao People's Democratic Republic scored 41.4% in the overall indicator category, which is lower than the global average of 54.6%1. This means that Lao has a relatively weak and challenging environment for digital health development and implementation (Fig. 10.5).

Lao's journey in the realm of digital health reveals a constellation of strengths and accomplishments that underscore the nation's commitment to harnessing technology for healthcare advancement. The presence of a national digital health vision statement, thoughtfully aligned with both the national health vision and the SDGs, signifies Lao's dedication to a unified and impactful digital health strategy. This strategic approach is fortified by the comprehensive coverage of diverse aspects of digital health within the national digital health policy, addressing critical elements such as data protection, privacy, security, ethics, and quality.

Lao's commitment to fostering a capable digital health workforce is evident through its comprehensive national digital health workforce assessment. This assessment illuminates the nation's focus on identifying current and future needs and gaps within its digital health workforce, ensuring its agility and relevance in a dynamic healthcare landscape. To nurture expertise and competence, Lao provides a comprehensive national digital health education and training mechanism, offering a range of courses and certifications tailored to elevate the proficiency of its digital health workforce.

Figure 10.5 Lao's digital health phase overview. *From Global Digital Health Monitor (2023).*

In tandem with its workforce focus, Lao has taken strides to assess and enhance the availability and effectiveness of digital health solutions within its borders. The presence of a national digital health services and applications assessment underscores the nation's commitment to ensuring the quality and accessibility of these solutions, effectively serving its population's healthcare needs. These achievements collectively embody Lao's proactive approach to digital health, underpinned by strategic planning and a dedicated commitment to nurturing its digital health ecosystem. Specifically for Laos, there is no dedicated digital health app at the moment. However, one of the leading digital health apps in Lao PDR is Khang Panya Lao, which serves as the national e-learning platform for education in the country. Established by the Ministry of Education and Sport (MoES) and UNICEF with the support of the European Union, Khang Panya Lao was created in response to the pandemic, lockdowns, and extended school closures. The app offers students and teachers access to online courses, learning materials, assessments, and feedback.

Malaysia

Based on the latest data from 2022, Malaysia scored 64.3% in the overall indicator category, which is higher than the global average of 54.6%1. This means that Malaysia

Figure 10.6 Malaysia's digital health phase overview. *From Global Digital Health Monitor (2023).*

has a relatively strong and supportive environment for digital health development and implementation. Malaysia's digital health landscape is marked by a range of strengths and achievements that underscore its commitment to fostering a robust environment for digital health development and implementation (Fig. 10.6). These achievements include a comprehensive national digital health vision statement that aligns seamlessly with the national health vision and the SDGs. The country's well-established national digital health steering committee plays a pivotal role in overseeing and coordinating digital health initiatives across diverse sectors and stakeholders. Additionally, Malaysia boasts a strong national digital health legislation that covers crucial aspects such as data protection, privacy, security, ethics, and quality. A dedicated national digital health focal point acts as a vital liaison for digital health matters at both the national and international levels. The formulation of a comprehensive national digital health strategy defines clear goals, objectives, priorities, and actionable steps for advancing digital health. Malaysia's commitment is further reflected in the existence of a national digital health investment plan that outlines budgetary requirements and sources for crucial initiatives.

Regulation and quality assurance are paramount, with Malaysia implementing a national digital health compliance mechanism that ensures the safety, quality, privacy, and security of digital health solutions. Workforce development is also prioritized through mechanisms such as a national digital health workforce assessment that identifies current and future needs, as well as a national digital health workforce strategy that addresses aspects like recruitment, retention, motivation, and performance. The presence of a national digital health workforce registry enhances efficient allocation.

Education and training are cornerstones of Malaysia's approach, with a national digital health education and training mechanism offering a diverse array of courses and certifications for the digital health workforce. Interoperability is upheld by a national digital health standards framework that fosters the adoption and implementation of global and regional standards. The adoption mechanism incentivizes the integration of agreed-upon standards, while an implementation mechanism ensures compliance and interoperability. Furthermore, Malaysia's commitment extends to infrastructure assessment, evaluating the availability and quality of both physical and technical components necessary for digital health progress. These collective efforts showcase Malaysia's dedication to advancing digital health for the benefit of its population and the broader healthcare landscape.

Several examples of digital health apps in Malaysia include DoctorOnCall, which is Malaysia's first and largest online healthcare platform. This app connects users to doctors, pharmacists, and specialists, enabling consultations through chat, voice, or video calls. Users can also order medicines, book lab tests, and access their medical records online. Additionally, DoctorOnCall offers health insurance and corporate wellness programs. Another notable app is BookDoc, a comprehensive healthcare platform that connects users to healthcare providers across Malaysia and other countries. It allows users to search, compare, and book appointments with various healthcare professionals such as doctors, dentists, physiotherapists, chiropractors, and more. BookDoc also provides health tips, rewards, and discounts for users who prioritize staying active and healthy.

Myanmar

Based on the latest data from 2022, Myanmar's overall indicator category score stood at 38.6%, which falls below the global average of 54.6%1. This indicates that Myanmar faces a relatively challenging and underdeveloped landscape for digital health advancement and implementation. Despite the challenges, Myanmar has managed to achieve some strengths in the realm of digital health. The country has established a national digital health vision statement that aligns harmoniously with both the national health vision and the SDGs. Myanmar also boasts a comprehensive national digital health policy that encompasses various facets of digital health, including data protection, privacy, security, ethics, and quality (Fig. 10.7).

In addition to these accomplishments, Myanmar's efforts extend to workforce development. The presence of a national digital health workforce assessment

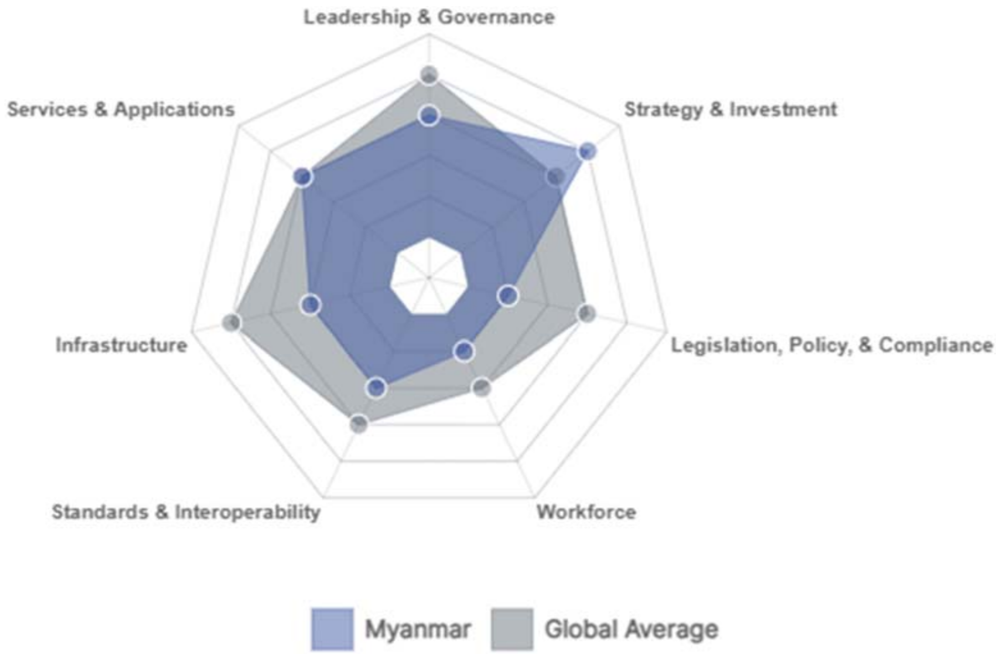

Figure 10.7 Myanmar's digital health phase overview. *From Global Digital Health Monitor (2023).*

mechanism aids in identifying the current and future requirements and gaps within the digital health workforce1. A dedicated national digital health education and training framework has been established, offering a variety of courses and certifications tailored to enhance the proficiency of the digital health workforce. Furthermore, Myanmar has undertaken a national digital health services and applications assessment to evaluate the availability and effectiveness of digital health solutions within its boundaries. Despite the relatively lower overall score, these efforts signify a notable commitment to advancing digital health in Myanmar.

Philippines

The Philippines stands as one of the nations that have undergone an assessment of their digital health enabling environment by the GDHM. This comprehensive evaluation employs seven key indicator categories, including Leadership & Governance, Strategy & Investment, Legislation, Policy, & Compliance, Workforce, Standards & Interoperability, Infrastructure, and Services & Applications, to track and measure progress. In light of the most recent data from 2022, the Philippines achieved a notable score of 58.6% in the overall indicator category, surpassing the global average of 54.6%. This higher score signifies that the Philippines boasts a relatively robust and

Figure 10.8 Philippines's digital health phase overview. *From Global Digital Health Monitor (2023).*

supportive foundation for the development and implementation of digital health initiatives (Fig. 10.8).

Among the country's commendable accomplishments and strengths in the realm of digital health are several key factors. These include the presence of a clear and all-encompassing national digital health vision statement that is aligned with both the national health vision and the SDGs. Additionally, the Philippines showcases the establishment of a well-structured national digital health steering committee, responsible for coordinating and overseeing digital health endeavors across diverse sectors and stakeholders. The nation also takes pride in its robust digital health legislation, which effectively addresses crucial aspects such as data protection, privacy, security, ethics, and quality.

Furthermore, the Philippines demonstrates its commitment through the presence of a dedicated national digital health focal point, ensuring streamlined communication and collaboration on digital health matters at both national and international levels. Notably, the country has devised a comprehensive national digital health strategy that defines the overarching goals, priorities, objectives, and actionable steps for the advancement of digital health. This strategy is further supported by a well-structured national digital health investment plan, outlining budgetary requirements and sources to facilitate the realization of these initiatives.

The Philippines places a strong emphasis on quality assurance, with a national digital health compliance mechanism in place to regulate, monitor, and evaluate the safety, quality, privacy, and security of digital health solutions. Workforce development is also a priority, evident through mechanisms such as a national digital health workforce assessment that identifies current and future needs and gaps. This dedication extends to areas like recruitment, retention, motivation, and performance of the digital health workforce, facilitated by a comprehensive national digital health workforce strategy.

To ensure the smooth interoperability of digital health solutions, the Philippines adheres to a national digital health standards framework that integrates global and regional standards and specifications for effective data exchange. This commitment is fortified by a well-established national digital health standards adoption mechanism that encourages the integration of agreed-upon standards by different users and providers of digital health solutions. Moreover, the nation employs a comprehensive national digital health standards implementation mechanism, which rigorously tests, certifies, or accredits compliance and interoperability.

Infrastructure development is also a priority for the Philippines, with the nation conducting thorough national digital health infrastructure assessments to gauge the availability and quality of physical and technical components. To complement this, the Philippines maintains a comprehensive national digital health infrastructure strategy, ensuring the effective development, deployment, and maintenance of these crucial components. This is supported by a meticulous national digital health infrastructure registry that keeps track of inventory and updates. Maintenance and improvement of this infrastructure are facilitated through a well-structured national digital health infrastructure management mechanism.

The Philippines' achievements extend to the realm of services and applications, with a national digital health services and applications assessment that evaluates the availability and efficacy of digital health solutions within the country. Guiding these efforts is a comprehensive national digital health services and applications strategy that steers the design, development, deployment, monitoring, evaluation, and scaling of impactful digital health solutions. The nation also maintains a meticulous national digital health services and applications registry that categorizes and lists active solutions, further supported by a dedicated management mechanism. In its holistic approach to digital health, the Philippines has demonstrated commendable efforts and achievements across various domains, signaling a promising trajectory for the advancement of digital health within the country.

Singapore

Based on the latest data collected in 2022, Singapore has achieved an impressive score of 79.3% in the overall digital health indicator category, which significantly surpasses

Figure 10.9 Singapore's digital health phase overview. *From Global Digital Health Monitor (2023).*

the global average of 54.6%. This remarkable achievement highlights Singapore's robust and highly supportive environment for the development and implementation of digital health initiatives (Fig. 10.9).

Singapore's strengths and achievements in the realm of digital health are multifaceted and comprehensive. The nation boasts a clear and comprehensive national digital health vision statement that is meticulously aligned with both the national health vision and the SDGs. This alignment underscores Singapore's commitment to integrating digital health solutions into its broader healthcare framework. The country's success is further evidenced by the establishment of a well-structured national digital health steering committee, which plays a pivotal role in overseeing and coordinating digital health endeavors across diverse sectors and stakeholders.

Singapore has also demonstrated a commitment to regulatory excellence with its robust national digital health legislation. This legislation comprehensively addresses a range of vital aspects, including data protection, privacy, security, ethics, and quality. This legal framework provides a solid foundation for ensuring the safe and ethical implementation of digital health solutions.

The nation's dedication to digital health is further exemplified by its establishment of a dedicated national digital health focal point, which serves as a central contact and liaison for digital health matters both domestically and on the international stage. This commitment extends to the formulation of a comprehensive national digital health strategy, which defines clear goals, objectives, priorities, and actionable steps for the advancement of digital health.

Singapore's holistic approach is underpinned by a well-crafted national digital health investment plan that outlines budgetary requirements and funding sources, ensuring the sustained development and implementation of digital health initiatives. A robust national digital health compliance mechanism adds a layer of quality assurance, regulating, monitoring, and evaluating the safety, quality, privacy, and security of digital health solutions.

The nation's investment in human resources is evident through its comprehensive national digital health workforce assessment, identifying current and future needs and gaps in the digital health workforce. This commitment to workforce development is complemented by a comprehensive strategy addressing recruitment, retention, motivation, and performance.

To ensure seamless interoperability, Singapore adheres to a national digital health standards framework, adopting and implementing global and regional standards and specifications for data exchange. This dedication to standards is reinforced by a well-structured national digital health standards adoption mechanism, fostering integration by various users and providers of digital health solutions. Moreover, a rigorous standards implementation mechanism tests, certifies, or accredits compliance and interoperability.

Singapore's comprehensive approach extends to infrastructure, with meticulous assessments of availability and quality. The nation maintains a robust national digital health infrastructure strategy, ensuring effective development, deployment, and maintenance of vital components. The infrastructure's inventory is meticulously tracked and updated through a well-organized national digital health infrastructure registry.

Singapore excels in digital health services and applications, as evidenced by assessments evaluating availability and effectiveness. The country maintains a comprehensive strategy guiding design, development, deployment, monitoring, evaluation, and scaling. This is supported by a meticulous registry listing and categorizing active solutions, with dedicated management mechanisms in place.

Furthermore, Singapore's commitment to digital health is reflected in news articles, such as The Straits Times, that highlight the nation's utilization of artificial intelligence to enhance healthcare outcomes and efficiency. The Ministry of Health Singapore has also published a report showcasing digital health projects supporting the national health vision of "One Singaporean, One Health Record." Additionally, the Health Sciences Authority Singapore provides valuable guidance through web-based resources, offering an overview of regulatory frameworks for digital health products. Singapore's remarkable achievements across these diverse domains underscore its leadership in fostering an environment that not only embraces but excels in the realm of digital health development and implementation.

Thailand

Based on the most recent data available from 2022, Thailand has achieved a score of 54.3% in the overall digital health indicator category, which closely aligns with the global average of 54.6%. This implies that Thailand's environment for digital health development and implementation is characterized by a moderate and well-balanced framework (Fig. 10.10).

Thailand's noteworthy strengths and accomplishments within the realm of digital health encompass a spectrum of essential facets: The country maintains a distinct and comprehensive national digital health vision statement that harmonizes with both the national health vision and the SDGs, emphasizing a holistic approach to integrating digital solutions into healthcare. Thailand's commitment to progress is underscored by a national digital health strategy, meticulously outlining goals, objectives, priorities, and strategic actions to steer the course of digital health development and implementation. A strategic and fiscally structured national digital health investment plan serves to precisely outline the financial prerequisites and funding sources that underpin various digital health initiatives. Thailand's meticulous attention to its human resources manifests through a well-crafted national digital health workforce assessment, discerning current and future requirements and gaps within the digital health workforce.

Figure 10.10 Thailand's digital health phase overview. *From Global Digital Health Monitor (2023).*

The nation's commitment to workforce capacity-building is fortified by an extensive national digital health education and training mechanism, offering a diverse array of courses and certifications for the digital health workforce. To ensure seamless interoperability, Thailand adheres to a national digital health standards framework that systematically adopts and implements pertinent global and regional standards and specifications for effective data exchange and interoperability. Efforts are also directed towards assessing the efficacy and availability of digital health solutions within the country through a comprehensive national digital health services and applications assessment.

These strengths are complemented by news articles, such as those from The Nation Thailand, which highlight how the nation is capitalizing on artificial intelligence to enhance healthcare efficiency and outcomes. The nation's dedication is further supported by reports from authoritative sources like the World Bank, showcasing digital health projects and programs contributing to the realization of the national health vision of "Healthy Thailand 4.0." The Ministry of Public Health Thailand's web-based resource offers insights into the country's digital health strategy and roadmap, providing valuable guidance to both practitioners and stakeholders. Thailand's achievements across these domains demonstrate a purposeful and balanced approach to digital health development, reflecting a commitment to enhancing healthcare outcomes through strategic and well-coordinated initiatives.

Vietnam

Based on the latest data available from 2022, Vietnam's digital health landscape received a score of 38.6% in the comprehensive indicator category, a figure that falls below the global average of 54.6%. This outcome underscores Vietnam's ongoing challenges and the relative weakness of its environment for digital health development and implementation (Fig. 10.11).

Despite these challenges, Vietnam has demonstrated notable strengths and accomplishments in the realm of digital health: The country has established a clear and congruent national digital health vision statement that aligns harmoniously with both the national health vision and the SDGs, emphasizing a holistic approach to integrating digital innovations into the healthcare sector. Vietnam's commitment to digital health is further solidified through a comprehensive national digital health policy, which encompasses diverse aspects of digital health including data protection, privacy, security, ethics, and quality.

The country's dedication to enhancing its healthcare workforce is evident in its systematic approach of conducting a national digital health workforce assessment, pinpointing existing and future needs and gaps within the digital health workforce. An elaborate national digital health education and training mechanism complements these efforts, offering diverse courses and certifications aimed at empowering the digital health workforce with up-to-date knowledge and skills. The nation's proactive approach extends to

Figure 10.11 Vietnam's digital health phase overview. *From Global Digital Health Monitor (2023).*

evaluating the effectiveness and availability of digital health solutions through a comprehensive national digital health services and applications assessment.

Furthermore, Vietnam's commitment to innovative healthcare practices is showcased through news articles like the one from UNDP Vietnam, highlighting the integration of telehealth to enhance healthcare access for remote and underserved communities. Additionally, a report from the World Health Organization (WHO) Vietnam highlights the implementation of digital health projects and programs that align with the national health vision of "Healthy and Happy Vietnam." To provide further insights, the Ministry of Health Vietnam offers a web-based resource that presents a detailed overview of the nation's digital health strategy and roadmap, furnishing valuable guidance to practitioners and stakeholders alike.

Despite the challenges posed by its lower indicator score, Vietnam's pursuit of these strengths and initiatives exemplifies a proactive and dynamic approach to embracing digital health advancements, fostering the potential for positive transformation in healthcare accessibility and quality.

Conclusion

The research has provided valuable insights into the state of digital health across ASEAN member countries by leveraging the comprehensive framework of the

GDHM and its dataset. The findings have illuminated strengths, gaps, and opportunities within the digital health ecosystems of these nations, guiding policymakers, healthcare leaders, and stakeholders in their efforts to enhance digital health integration and healthcare outcomes. Looking forward, future research could delve deeper into specific contextual factors that influence the varying levels of digital health adoption within ASEAN, as well as explore the long-term impact of digital health initiatives on healthcare access, quality, and equity. Additionally, conducting comparative studies between ASEAN and other regions could yield cross-cultural insights and strategies to further advance digital health agendas. The continued utilization of evidence-based assessments, like the GDHM, will play a pivotal role in shaping the trajectory of digital health in ASEAN and beyond, ensuring its alignment with emerging technologies and changing healthcare landscapes.

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CHAPTER 11

A comparative evaluation of the use of social media platforms by multinational and Indian pharmaceutical companies

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Introduction

The development of the Internet and its related technologies such as social media platforms have become increasingly useful. A single definition of social media is difficult to give because social media is constantly evolving and has several facets. Generally, it is an Internet-based tool which helps people to gather information (collate, compile, and retrieve) and communicate the information with each other. It is built on the ideological and technological foundations of Web 2.0 and the users can create and share generated content. In general, social media can be classified into two components—media-related and social dimension (Moorhead et al., 2013).

The influence of social media has increased substantially in recent years as more and more people join online communities (Tuten & Solomon, n.d.). The most important community is Facebook followed by YouTube. In India, 250,000 people use Facebook which is among the highest in the world (Chaffey, n.d.). Tough Facebook is a US-based organization, and most users of Facebook reside in the Asia-Pacific region. While Facebook is very popular with individuals, LinkedIn is an important platform for companies. The companies use this channel primarily as a recruiting tool (Hird, 2009). The worldwide number of internet users in 2018 is about 4.021 billion people. Of these 3.196 billion people use social media (Chaffey, n.d.). The number of social media users reached up by 13% from January 2017 to January 2018. The highest rates of social media users are in Southeast Asia, which includes India. The biggest growth of social media users in the period from January 2017 to January 2018 was in Saudi Arabia with 32% and in India with 31%. Since January 2017 the number of social media users in India increased by 59 million. A total of 462 million people in

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India are Internet users, which corresponds to a share of 34%. Of these, 250 million people are active on various social media platforms (Chaffey, n.d.).

With the growing use of social media, its use in the health sector has also increased. It has changed the nature and speed of the interaction between individuals and organizations across the healthcare systems. However, there are still big differences in the use of social media between the different countries in Europe. For example, the percentage of German hospitals using social media networks is in the single-digit range whereas, about 45% of Norwegian and Swedish hospitals use LinkedIn. Moreover, about 22% of Norwegian hospitals use Facebook to communicate and interact with patients (Moorhead et al., 2013). This is one of the ways to share health information and information about diseases among people and discuss healthcare policy and practice issues. Furthermore, physicians can communicate with their patients and they can provide health information to the community thereby building a professional network. Patients, on the other hand, can educate communities about diseases and they can discuss with other patients about their experiences (Ventola, 2014).

Social media is not only important for physicians and patients but also for pharmaceutical companies. Pharmaceutical companies today can use social media not just as a tool to broadcast their own message but are now able to provide overall care with the help of active monitoring and remote diagnosis. Hence, social media marketing has become important for finding out information about consumer behavior, market perceptions and new market opportunities. Also, pharmaceutical companies can use social media for a better relationship with patients (Agrawal & Kaur, 2015). In order to guarantee the correctness of the information, pharmaceutical companies should have official social media accounts. In this way, the companies can document what information consumers receive when they search for drug information on social media sites (Tyrawski & De Andrea, 2015). Gao et al. (2022) found that social media can reduce the time to recall a pharmaceutical product based on adverse drug reaction discussions of social media and can be used in pharmacovigilance. Pool et al. (2022) found that social media can help public health authorities to devise strategies to address the concerns of telehealth users with an improved experience.

Social media has its own challenges and limitations. Due to its ease of reach and access, social media can be one of the sources of misinformation for the general public regarding the use of pharmaceutical and healthcare products. A study by Di Domenico et al. (2022) found that social media could be one of the platforms to spread misinformation about vaccines. It was evident even during the COVID-19 pandemic that various social media platforms had varied information about the use of medicines, especially vaccines. It becomes imperative for healthcare professionals and social media platforms to exercise caution while sharing content on social media so that it provides relevant and possibly accurate information about healthcare-related issues. Sule et al. (2023) found that in the US, physicians were sharing misinformation on social media about vaccines, mask efficacy, negative consequences etc.

This paper aims to analyze the social media use of the pharmaceutical industry on various social media platforms such as Twitter, YouTube, Facebook, LinkedIn, Instagram, and Pinterest. Currently, there is a lack of information about which social media channels are used by pharmaceutical companies and what information is shared on them. The aim of this paper was to review and compare all social media channels of the top 25 multinational (MNC) and top 25 Indian pharmaceutical companies. The paper analyses the extent of use by Indian and MNC companies for the use of social media platforms as well as the number of followers/users/viewers of their social media platforms.

Methods

This study is an exploratory research using available information on various social media platforms regarding pharmaceutical companies and their social media use. The various social media platforms such as Twitter, YouTube, Facebook, LinkedIn, Instagram, and Pinterest of the top 25 Indian and top 25 MNC pharmaceutical companies were mined. The study also attempts to understand the extent of social media use by Indian and MNC pharmaceutical companies. Official social media platforms like Twitter, Facebook, YouTube, LinkedIn, Instagram, and Pinterest as listed for each of the companies were searched, retrieved and tabulated. For each social media platform, the number of users/followers/subscribers/viewers as well as the information provided on these platforms was listed. This information is useful to compare the use of social media by Indian and MNC pharmaceutical companies and may help identify the most popular social media platform preferred by the companies. The data was collected for a period of one and a half months between September and October 2018. The data obtained was compiled as separate tables for Indian and MNC companies.

Results

Social medial accounts of MNC pharma companies

It was found that most MNC pharmaceutical company has their own verified Twitter account except Teva Pharmaceuticals and Daiichi Sankyo with only a Japanese Twitter account with content and a global account without any posts. The content posted on these verified accounts includes news about the company, current health issues and diseases information, social commitment initiatives, conferences attended and employee interviews which normally are in the form of short files with employees who talk about the company and the workplace. The results are shown in Table 11.1.

Table 11.1 Multinational pharmaceutical companies and their social media accounts.

Rank	Name of company	Presence on social media platforms	Twitter	Linked In	Youtube	Facebook	Instagram	Pinterest	Flickr
1	Pfizer (US)	Twitter, Linked In, YouTube, Facebook, Instagram	Pfizer Inc. Verified account @pfizer Tweets: 7910 Following: 2442 Followers: 230,000 Likes: 480	Pfizer Follower: 2,017,257	Pfizer Subscribers: 21,670	Pfizer Verified account Likes: 345,469	Pfizer Inc Verified account Posts: 266 Followers: 13,100 Following: 272		
2	Novartis (Switzerland)	Twitter, Linked In, YouTube, Facebook, Instagram, Pinterest	Novartis Verified account @Novartis Tweets: 11,500 Following: 532 Followers: 240,000 Likes: 341	Novartis Follower: 1,390,642	Novartis Subscribers: 11,642	Novartis Verified account @Novartis Likes: 324,710	Novartis Verified account Posts: 550 Followers: 33,600 Following: 62	Novartis Followers: 1906 Following: 52	
3	Roche (Switzerland)	Twitter, Linked In, YouTube, Facebook	Roche Verified account @Roche Tweets: 10,600 Following: 1683 Followers: 182,000 Likes: 1.015	Roche Follower: 903,486	Roche Subscribers: 14,205	Roche @RocheCareers Likes: 87,388			
4	Merck & Co Inc (US)	Twitter, Linked In, YouTube, Facebook, Instagram	Merck Verified account @Merck Tweets: 6920 Following: 1010 Followers: 159,000 Likes: 1459	Merck Follower: 816,204	Merck Subscribers: 1775	Merck Verified account @MerckInvents Likes: 90,223	Merck Verified account Posts: 144 Followers: 11,000 Following: 82		
5	Sanofi (France)	Twitter, Linked In, YouTube, Facebook, Instagram	Sanofi Verified account @sanofi Tweets: 4868 Following: 232 Followers: 105,000 Likes: 88	Sanofi Follower: 1,170,630	Sanofi Subscribers: 15,993	Sanofi US @sanofiUS Likes: 47,004	Sanofi Posts: 105 Followers: 6519 Following: 5		

6	Johnson & Johnson (US)	Twitter, Linked In, YouTube, Facebook	Johnson & Johnson Verified account @JNJNews Tweets: 12,200 Following: 2537 Followers: 170,000 Likes: 2346	Johnson & Johnson Follower: 2,061,016	Johnson & Johnson Subscribers: 22,162	Johnson & Johnson Verified account @jnj Likes: 792,823			
7	Gilead Sciences (US)	Twitter, Linked In, YouTube, Facebook	Gilead Sciences Verified account @GileadSciences Tweets: 2614 Following: 198 Followers: 29,300 Likes: 707	Gilead Sciences Follower: 200,501	Gilead Sciences Subscribers: 2645	Gilead Sciences Verified account @GileadSciences Likes: 6369			
8	GSK (United Kingdom)	Twitter, Linked In, YouTube, Facebook, Instagram, Flickr	GSK Verified account @GSK Tweets: 10,100 Following: 532 Followers: 169,000 Likes: 1120	GSK Follower: 1,318,587	GSK Verified account Subscribers: 12,242	GSK Verified account @GSK Likes: 288,298	GSK Verified account Posts: 181 Followers: 17,700 Following: 122		GSK Glaxo SmithKline Followers: 243 Following: 8
9	AbbVie (US)	Twitter, Linked In, YouTube, Facebook, Instagram	AbbVie Verified account @abbvie Tweets: 4844 Following: 479 Followers: 46,800 Likes: 608	AbbVie Follower: 262,909	AbbVie 198.419 views	AbbVie Verified account @AbbVieGlobal Likes: 18,034	Abbvie Verified account Posts: 24 Followers: 1372 Following: 28		
10	Amgen (US)	Twitter, Linked In, YouTube, Facebook, Instagram, Flickr	Amgen Verified account @Amgen Tweets: 7708 Following: 74 Followers: 69,600 Likes: 184	Amgen Follower: 378,126	Amgen Subscribers: 13,823	Amgen Careers @amgencareers Likes: 12,774	Amgencareers Posts: 132 Followers: 1480 Following: 39		Amgen Inc Followers: 11 Following: 0
11	AstraZeneca (United Kingdom)	Twitter, Linked In, YouTube, Facebook, Instagram	AstraZeneca Verified account @AstraZeneca Tweets: 5666 Following: 1349 Followers: 147,000 Likes: 2163	AstraZeneca Follower: 785,094	AstraZeneca Subscribers: 1920	Astra Zeneca Careers @astrazenecacareers Likes: 28,169	AstraZeneca_Careers Posts: 1186 Followers: 5071 Following: 511		

(*Continued*)

Table 11.1 (Continued)

Rank	Name of company	Presence on social media platforms	Twitter	Linked In	Youtube	Facebook	Instagram	Pinterest	Flickr
12	Allergan (Ireland)	Twitter, Linked In, YouTube	Allergan plc Verified account @Allergan Tweets: 342 Following: 149 Followers: 24,300 Likes: 869	Allergan Follower: 334,266	Allergan plc Subscribers: 94				
13	Teva Pharmaceut. Industries (Israel)	Twitter, Linked In, YouTube, Facebook, Instagram	Teva Pharmaceuticals @tevapharm Tweets: 0 Following: 9 Followers: 2890 Likes: 0	Teva Pharma ceuticals Follower: 325,764	Teva Pharmaceutical Industries Ltd. 122,058 views:	Teva Pharma ceutical Industries Ltd. @tevapharm Likes: 35,968	Teva pharm Posts: 4 Followers: 667 Following: 3		
14	Bristol-Myers-Squibb (US)	Twitter, Linked In, YouTube, Facebook	Bristol-Myers Squibb Verified account @bmsnews Tweets: 6143 Following: 1092 Followers: 125,000 Likes: 521	Bristol-Myers Squibb Follower: 488,145	Bristol-Myers Squibb Subscribers: 1224	Bristol-Myers Squibb Verified account @Bristol Myers Squibb Likes: 121,290			
15	Eli Lilly (US)	Twitter, Linked In, YouTube, Facebook, Instagram, Pinterest	Eli Lilly and Company Verified account @LillyPad Tweets: 20,300 Following: 1353 Followers: 107,000 Likes: 1,397	Eli Lilly and Company Follower: 567,141	Eli Lilly and Company Subscribers: 1775	Eli Lilly and Company Verified account @elilillyandco Likes: 179,411	Eli Lilly co Posts: 463 Followers: 10,600 Following: 61	Eli Lilly Followers: 51 Following: 54	
16	Bayer (Germany)	Twitter, Linked In, YouTube, Facebook, Instagram, Pinterest, Flickr	Bayer AG Verified account @Bayer Tweets: 7173 Following: 2333 Followers: 156,000 Likes: 4414	Bayer Follower: 1,156,204	Bayer Global Subscribers: 14,622	Bayer Verified account @Bayer Likes: 2,782,621	Bayer official Verified account Posts: 435 Followers: 38,900 Following: 50	Bayer Followers: 399 Following: 9	Bayer AG Followers: 15 Following: 0

17	Novo Nordisk (Denmark)	Twitter, Linked In, YouTube, Facebook, Instagram	Novo Nordisk Verified account @novonordisk Tweets: 3095 Following: 1842 Followers: 27,300 Likes: 4232	Novo Nordisk Follower: 592,138	Novo Nordisk Subscribers: 2966	Novo Nordisk Verified account @novonordisk Likes: 526,132	NovoNordisk Posts: 419 Followers: 18,200 Following: 229		
18	Boehringer Ingelheim (Germany)	Twitter, Linked In, YouTube, Facebook, Instagram, Pinterest, Flickr	Boehringer Ingelheim Verified account @Boehringer Tweets: 13,100 Following: 3860 Followers: 85,500 Likes: 2408	Boehringer Ingelheim Follower: 568,942	Boehringer Ingelheim Subscribers: 5797	Boehringer Ingelheim Verified account @boehringe ringelheim Likes: 1,087,896	boehringer_ingelheim Verified account Posts: 487 Followers: 11,200 Following: 67	Boehringer Ingelheim Followers: 1193 Following: 176	Boehringer Ingelheim Followers: 20 Following: 0
19	Takeda (Japan)	Twitter, Linked In, YouTube, Facebook, Instagram	Takeda @TakedaPharma Tweets: 1050 Following: 219 Followers: 7645 Likes: 229	Takeda Follower: 312,578	Takeda Oncology Subscribers: 162	Takeda Oncology @TakedaOncology Likes: 130,065	takedaoncology Posts: 278 Followers: 1243 Following: 109		
20	Celgene (US)	Twitter, Linked In, YouTube, Facebook, Instagram, Pinterest	Celgene Corporation Verified account @Celgene Tweets: 5538 Following: 1213 Followers: 21,300 Likes: 1,922	Celgene Follower: 176,795	Celgene Subscribers: 1245	Celgene Verified account @Celgene Likes: 8498	celgene Posts: 91 Followers: 885 Following: 38	Celgene Corporation Followers: 496 Following: 18	
21	Astellas Pharma (Japan)	Twitter, Linked In, YouTube, Facebook	Astellas Pharma US Verified account @AstellasUS only for the US audience Tweets: 3441 Following: 1241 Followers: 43,900 Likes: 373	Astellas Pharma Follower: 122,408	AstellasUS only for the US audience Subscribers: 323	Astellas Verified account @AstellasUS only for The US audience Likes: 4271			

(*Continued*)

Table 11.1 (Continued)

Rank	Name of company	Presence on social media platforms	Twitter	Linked In	Youtube	Facebook	Instagram	Pinterest	Flickr
22	Shire (Ireland)	Twitter, Linked In, YouTube	Shire plc Verified account @Shireplc Tweets: 2595 Following: 1062 Followers: 7272 Likes: 223	Shire Follower: 149,568	Shire plc Subscribers: 685				
23	Mylan (US)	Twitter, Linked In, YouTube, Facebook	Mylan Verified account @MylanNews Tweets: 1421 Following: 198 Followers: 8027 Likes: 441	Mylan Follower: 187,910	Mylan Subscribers: 984	Mylan France Verified account @MylanFrance Likes: 19,194			
24	Biogen Inc (US)	Twitter, Linked In, YouTube, Facebook	Biogen Verified account @biogen Tweets: 3673 Following: 252 Followers: 21,900 Likes: 498	Biogen Follower: 185,630	Biogen Subscribers: 1089	Biogen @biogen Likes: 4276			
25	Daiichi Sankyo (Japan)	Twitter, Linked In, YouTube, Facebook, Instagram	Japan: 第一三共株式会社 @DaiichiSankyoJP Tweets: 469 Following: 0 Followers: 547 Likes: 1 Global: Daiichi Sankyo @DaiichiSankyo Tweets: 0 Following: 3 Followers: 250 Likes: 0	Daiichi Sankyo, Inc. (US) Follower: 62,966	Official channel Daiichi Sankyo Healthcare (Japan) Subscribers: 3125 Daiichi Sankyo Europe GmbH 24,352 views	Global: Daiichi Sankyo Co., Ltd. @daiichisankyo Likes: 206	daiichisankyojp (Japan) Posts: 0 Followers: 10 Following: 0 daiichisankyo (Global) Posts: 0 Followers: 62 Following: 0		

Popular social media accounts and reach

In terms of followers on Twitter, Novartis has the highest number of followers (240,000) followed by Pfizer (230,000), and Roche (182,000). In total, the top 10 of the 25 biggest MNC pharmaceutical companies in the world have more than 1,000,000 followers on Twitter. The highest number of tweets were posted by Eli Lilly (20,000) followed by Boehringer Ingelheim (13,000) and Johnson & Johnson (12,000).

Another important social media platform for MNC companies is LinkedIn. All 25 companies have their own account and every company has content posted on their account. The content includes information about the research process and interviews as well as a short presentation of the employees of the companies. Furthermore, there is information about conferences, social commitments, quarterly reports, collaboration and partnerships with other companies, and initiatives and funded projects. Many companies present information about their Foundation on their programmes on these platforms such as Novartis' Next Generation Program, #AbbVieLife, Amgen Foundation, #BoldForLife of Allergan and BMS Foundation of Bristol-Myers-Squibb. Astellas Pharma even has information on competition posted for new ideas called C3Prize. Johnson & Johnson has the highest followers on LinkedIn (2,061,016) followed by Pfizer (2,017,257) and Novartis (1,390,642).

YouTube is yet another important social media platform for pharmaceutical companies. All top 25 MNC pharmaceutical companies have their own YouTube channel but only GSK has a verified account. These channels are used for educational and informative videos about various topics. For example, the videos by Pfizer include information about their science, purpose, one's health, annual report, the products, etc. Novartis has its own videos about the Novartis mission leadership, social business, patient stories, and researches. Furthermore, most companies post videos about important diseases, the research process, health tips for patients and about working at the company. AbbVie, Teva Pharmaceuticals Industries Ltd. and Daiichi Sankyo Europe have specified the number of views. The account of Astellas Pharma is only for the US audience and they have no further account. Johnson and Johnson has the most subscribers (22,000) followed by Pfizer (21,000) and Sanofi (16,000).

In comparison, Facebook is not as important for the companies as the other three channels. Of the top 25 worldwide companies only 15 have a verified Facebook account. Mylan has only one Facebook account which is specifically meant for a French audience. Sanofi and Astellas Pharma have only an account for the US audience. Some companies have Facebook pages only highlighting career opportunities, for example, Roche Careers, Amgen Careers, and AstraZeneca Careers. Teva Pharmaceutical Industries, Takeda Oncology, and Biogen have only an unofficial account. The content on the Facebook pages is similar to the content of the single Twitter accounts. The companies post content about current health issues and diseases, research results, congresses, partnerships with other companies and their social commitment. Furthermore, they post interviews and stories about patients and employees. On the career pages, information about job offers and news about the company is provided. There are also short videos with employee interviews who talk about their work experience at the companies. The German companies Bayer and Boehringer Ingelheim have the most Facebook followers of all 25 companies; over 2.7 million followers for Bayer Global and over 1 million followers for Boehringer Ingelheim. The third is Johnson & Johnson with almost 800,000 followers.

A very popular social media platform with an increasing number of followers for pharmaceutical companies is Instagram. Compared to Facebook this platform is not used so much. Only seven of the 25 biggest pharmaceutical companies in the world have a verified account on Instagram. AstraZeneca and Amgen use Instagram more than Facebook as a career page. Ten of the 25 companies were not active on this platform until September 2018. Sanofi, Teva Pharmaceuticals, Eli Lilly, Novo Nordisk, Takeda, and Celgene have no official account on Instagram until September 2018. Bayer has the highest number of followers on Instagram with almost 39,000 followers. The two other companies with the most followers are Novartis (33,000) and GSK (17,000) followers.

Presence on emerging social media platforms

The analysis also looked at the other two social media platforms—Pinterest and Flickr. Only a few companies are active on these platforms. On Pinterest, only five of the 25 companies have their own account. Eli Lilly has an account on this platform, but content is not posted. The other four companies on Pinterest are Novartis, Bayer, Boehringer Ingelheim, and Celgene which post information about various topics. While Novartis posts content to the category's quotable science, beautiful medicine, 365 days of MSLifeHacks, and infographics, Bayer posts pictures about the Bayer history, the anniversary tour, the best of science, and other activities. Celgene uses the channel to educate society and the community about different forms of cancers like pancreatic cancer and breast cancer, and its management. Boehringer Ingelheim posts information about scleroderma, the annual press, conferences, etc. Novartis has over 1900 followers, followed by Boehringer Ingelheim (1200), Celgene (500), and Bayer (400).

Flickr is not used by pharmaceutical companies. Only Glaxo Smith Kline has an account. On this account are albums about leadership, history, and a few more. The number of followers is only almost 250. A detailed analysis of Pinterest and Flickr was not carried out as they are the least used social media platforms.

Social media accounts of Indian pharmaceutical companies

The second part of the analysis was to find out information about the social media activities of the top 25 pharmaceutical companies in India. It was noted that only a few Indian pharmaceutical companies use social media to inform the public about the company and its activities. Many companies do not have a social media platform or activity listed. This is shown in table 11.2.

Social media accounts and reach

In comparison to MNC pharmaceutical companies, a few Indian pharmaceutical companies use social media including a Twitter account. Of a total of the 25 top companies, only 13 have a Twitter account. Intas has an account but they do not use it to share information. Torrent Pharma has no posts since June 2017. Of these 13 Indian companies, five are MNC companies with their subsidiary in India including Abbott, GSK, Pfizer, Sanofi, and Novartis. All five companies have a verified Twitter account where they post content about company news, employee interviews, events and congresses, current health issues, and diseases and information about new research results. The eight Indian companies—Sun Pharma, Cipla, Zydus Cadila, Mankind, Alkem, Lupin, Dr. Reddy's, and Wockhardt have Twitter accounts which are not verified. The most shared information is about current disease topics, articles about launches of new generic products, quarterly reports, events and congresses, and awards received. Wockhardt has an account which is linked to Wockhardt Foundation. The Indian company with the most followers on Twitter is Dr. Reddy's (7200) followed by Sun Pharma (6800 followers) and Cipla (5600 followers). Concurrently Dr. Reddy's posted more than 4200 tweets which is the highest of all companies, but the number of likes is only 550. The best company in this category is Cipla with over 4400 likes.

The most used platform of Indian companies is LinkedIn. Every company in the top 25 has its own account on this platform. However, six of these do not use their account to post any content about the company. Sun Pharma has the most followers on LinkedIn (210,000) followed by Dr. Reddy's (194,000) and Cipla with 191,000 followers. The global companies that operate in India are excluded here. The content posted by the Indian companies is about current health topics, diseases, events and congresses, information about different topic days like Independence Day, employee interviews and job opportunities.

The social media channel YouTube is also very less used by Indian companies. In the analysis, the five MNCs operating and among the top 25 are excluded. Of the other 15 companies, nine have a YouTube channel. Bal Pharma though has a YouTube channel, but the company has not posted videos and has only 24 subscribers until September 2018. Torrent Pharma also posted only one video about the Torrent Way. Most companies have their corporate video explaining what they do and about the vision and mission of the company. Sun Pharma has its corporate video in six different languages. But Mankind Pharma has the most subscribers on YouTube (40,000), while Cipla has the second highest subscribers (1500) and Sun Pharma with third highest subscribers (1000).

Table 11.2 Indian pharmaceutical companies and their social media accounts.

Rank	Name of company	Presence on social media platforms	Twitter	Linked In	Youtube	Facebook	Instagram	Flickr
1	Sun + Ranbaxy	Twitter, Linked In, YouTube, Facebook	Sun Pharma @SunPharma_Live Tweets: 681 Following: 17 Followers: 6796 Likes: 26	SUN PHARMA Follower: 210,240	Sun Pharma Subscribers: 1067	Sun Pharma Likes: 19,644		
2	Abbott + Abbott HC + Novo	Twitter, Linked In, YouTube, Facebook, Instagram	Abbott Verified account @AbbottGlobal Tweets: 4088 Following: 3165 Followers: 28,600 Likes: 4,851	Abbott Follower: 1,176,710	Abbott India Subscribers: 8781	Abbott Verified account @Abbott Likes: 206,854	abbottglobal Verified account Posts: 672 Followers: 17,900 Following: 2473	
3	Cipla	Twitter, Linked In, Youtube, Facebook	Cipla @Cipla_Global Tweets: 3281 Following: 126 Followers: 5653 Likes: 4406	Cipla Follower: 191,148	Cipla Subscribers: 1439			
4	Zydus + Biochem	Twitter, Linked In, Facebook	Zydus Cadila @ZydusUniverse Tweets: 513 Following: 42 Followers: 2605 Likes: 154	Zydus Group Follower: 89,410		Zydus Cadila Likes: 12,762		
5	Mankind	Twitter, Linked In, Youtube, Facebook, Instagram	Mankind Pharma @Pharma_Mankind Tweets: 430 Following: 213 Followers: 697 Likes: 34	MANKIND PHARMA LTD Follower: 45,029	Mankind Pharma Subscribers: 39,449	Mankind Pharma Limited @MankindPharmaIndia Likes: 23,450		
6	Alkem + Cachet + Indchemie	Twitter, Linked In, YouTube, Facebook	Alkem Laboratories Ltd. @Alkem_Lab Tweets: 92 Following: 0 Followers: 260 Likes: 3	Alkem Laboratories Ltd. Follower: 55,401	Alkem Laboratories Subscribers: 101	ALKEM Laboratories Ltd. @alkemlabsltd Likes: 2080		
7	Lupin	Twitter, Linked In, YouTube, Facebook	Lupin @LupinGlobal Tweets: 501 Following: 383 Followers: 5053 Likes: 611	Lupin Follower: 15,907	No own channel	Lupin Ltd. Likes: 4128		

8	Glaxo	Twitter, Linked In, Youtube, Facebook, Instagram, Flickr,	GSK Verified account @GSK Tweets: 10,100 Following: 532 Followers: 169,000 Likes: 1120	GSK Follower: 1,318,587	GSK Verified account Subscribers: 12,242	GSK Verified account @GSK Likes: 288,298	gsk Verified account Posts: 181 Followers: 17,700 Following: 122	GSK GlaxoSmithKline Followers: 243 Following: 8
9	Macleods	Linked In, Facebook		MACLEODS PHARMACEUTICALS LTD. Follower: 14,695		Macleods Pharmaceuticals LTD Likes: 7870		
10	Intas	Twitter, Linked In, Facebook	Intas Oncology @IntasOncology Tweets: 5 Following: 0 Followers: 15 Likes: 0	Intas Pharmaceuticals Follower: 29,100		Intas Pharmaceuticals Likes: 14,790		
11	Emcure + Zuventus	Linked In, Facebook		Emcure Pharmaceuticals Limited Follower: 20,550		Emcure Pharmaceuticals Limited @emcurepharmaofficial Likes: 13,657		
12	Pfizer	Only global social media activities	Pfizer Inc. Verified account @pfizer Tweets: 7910 Following: 2442 Followers: 230,000 Likes: 480	Pfizer Follower: 2,017,257	Pfizer Subscribers: 21,670	Pfizer Verified account Likes: 345,469	pfizerinc Verified account Posts: 266 Followers: 13,100 Following: 272	
13	Aristo	Linked In, Facebook		Aristo Pharmaceuticals Pvt. Ltd. Follower: 3212		Aristo Pharmaceuticals Pvt. Ltd. @aristopharmaindia Likes: 4172		
14	Glenmark	Linked In		Glenmark Pharmaceuticals Follower: 122,289				
15	Sanofi India		Sanofi Verified account @sanofi Tweets: 4868 Following: 232 Followers: 105,000 Likes: 88	Sanofi Follower: 1,170,630	Sanofi Subscribers: 15,993	Sanofi US @sanofiUS Likes: 47,004	sanofi Posts: 105 Followers: 6519 Following: 5	
16	Torrent	Twitter, Linked In, Youtube, Facebook, Instagram	Torrent Pharma @TorrentPharmaIn Tweets: 0 Following: 0 Followers: 744 Likes: 5	Torrent Pharmaceuticals Ltd Follower: 59,493	Torrent Pharma Subscribers: 59	Torrent Pharmaceuticals Limited @TorrentPharmaceuticals Limited Likes: 49,321	torrentpharmaceuticals Posts: 0 Followers: 2205 Following: 0	

(*Continued*)

Table 11.2 (Continued)

Rank	Name of company	Presence on social media platforms	Twitter	Linked In	Youtube	Facebook	Instagram	Flickr
17	Dr. Reddys	Twitter, Linked In, Youtube, Facebook	Dr. Reddy's @drreddys Tweets: 4235 Following: 120 Followers: 7263 Likes: 550	Dr. Reddy's Laboratories Follower: 194,845	Dr. Reddy's Laboratories Subscribers: 921	Dr. Reddy's Laboratories Ltd. @Dr. ReddysLaboratoriesLtd Likes: 179,604		
18	USV	Linked In		USV PRIVATE LIMITED Follower: 29,596				
19	Micro + Bal	Linked In, YouTube, Facebook		Bal Pharma Limited Follower: 2324	Bal Pharma Ltd Subscribers: 24	Bal Pharma Ltd. Likes: 266		
20	Ipca	Linked In, Facebook		Ipca Laboratories Limited Follower: 49,005		Ipca Laboratories Ltd. Likes: 7727		
21	Alembic	Linked In, YouTube, Facebook		Alembic Pharmaceuticals Limited Follower: 28,328	Alembic Pharmaceuticals Ltd. Subscribers: 166	Alembic Pharmaceuticals Ltd @alembicpharmaceutical Likes: 15,738		
22	Wockhardt	Twitter, Linked In, Youtube, Facebook, Instagram	Wockhardt Foundation @WFIndia Tweets: 2601 Following: 21 Followers: 3358 Likes: 17	Wockhardt Ltd. Follower: 97,374	Wockhardt Limited Subscribers: 84	Wockhardt Foundation Verified account @WockhardtFoundation Likes: 144,817	wockhardtfoundation Posts: 409 Followers: 17,200 Following: 10	
23	Novartis	Only global social media activities	Novartis Verified account @Novartis Tweets: 11,500 Following: 532 Followers: 240,000 Likes: 341	Novartis Follower: 1,390,642	Novartis Subscribers: 11,642	Novartis Verified account @Novartis Likes: 324,710	novartis Verified account Posts: 550 Followers: 33,600 Following: 62	Novartis Followers: 1906 Following: 52
24	FDC	Linked In		FDC Limited Follower: 3,527				
25	Unichem	Linked In, Facebook		Unichem Laboratories Limited Follower: 28,587		Unichem Laboratories Ltd Likes: 542		

Indian pharmaceutical companies have no verified accounts on Facebook. The only verified account is of Wockhardt with their Wockhardt Foundation. In the case of Mankind Pharma there are two Twitter accounts—@Pharma_Mankind and @mankind_pharma. Of these two accounts, @Pharma_Mankind seems to be an authentic account whereas @mankind_pharma looks fake and dubious. Unless the company takes action to verify the authentic account, the chances of misinformation being spread through dubious account, affecting the image of the company, remains. Some companies have an account but have not used the account for some time like Sun Pharma since March 2018, Zydus Cadila since August 2015, Macleods since October 2017, and Intas since 2015. Only seven companies post content regularly on their account. The information available on Facebook accounts is similar to the information available on Twitter and LinkedIn. Dr. Reddy's has the most followers on Facebook (180,000) with Wockhardt Foundation being second with about 145,000 followers and on the third spot is Torrent Pharma with about 50,000 followers.

The analysis showed that Instagram is not an important social media platform for Indian companies. Only the two Indian companies Wockhardt and Mankind, and international companies like Abbott, GSK, Sanofi, Pfizer, and Novartis use Instagram to share information with the public. Although Torrent has an account with about 2200 followers, but the company has not posted anything since June 2017. Wockhardt uses the account to share information about the Wockhardt Foundation. The Foundation has about 17,200 followers on Instagram with more than 400 posts. Mankind has only about 800 followers and has only 26 posts. The posts are about tips for a better life quality and the vision of the company.

The platforms Flickr and Pinterest are not used by the Indian pharmaceutical companies and hence have been excluded from the analysis.

Discussion

Due to the rapid growth of the internet, the public and patients became active seekers and providers of healthcare information. Web 2.0 includes the growth of the social network and multidirectional communication with a strong social component compared to Web 1.0 (Liang & Mackey, 2011). Therefore, it can also be used as a marketing tool. The development of Web 2.0 technologies resulted in users being interactive with physicians and other patients and constantly looking for information about diseases and health status (Cormode & Krishnamurthy, 2008).

Surveys indicated that in 2009 about 60% of US citizens used the Internet for the first time to look for health-related information. In addition, access to the internet on mobile has made information on healthcare searchable 24 × 7 (Fox, 2011). In recent years the incidence of chronic diseases has been increasing, and patients are in search of information related to their state of health, lifestyle modifications, drugs available and other related information to manage or treat their diseases. Patients affected by the same disease/similar conditions can communicate with each other. For this reason, the role of health decision-making has increased rapidly (George et al., 2013).

According to a company survey looking for the most important social media platforms, Facebook has the most users with 67%. This is followed by LinkedIn with only 12% users. Other social media platforms that are used include Instagram, Twitter, YouTube, and Pinterest in this order (Social Media Examiner, 2018a, 2018b). In a study of about 5700 managers, it was found that companies plan to expand their activities on all social media portals in the future. 66% of the marketing managers said that their company would like to expand their presence on Instagram whereas Facebook was ranked second with 62% and YouTube as the third preference in terms of expansion with 58%. LinkedIn, Twitter and Pinterest were other media platforms where companies wanted to expand (Social Media Examiner, 2018a, 2018b).

As users are becoming technology savvy, companies are using social media platforms as marketing tools. Further, in India, the penetration and access to the internet in the last few years have improved substantially with good connectivity. Despite the increasing population having access to social media, the uptake of social media in the pharmaceutical industry is limited. However, MNC pharmaceutical companies have a strong presence on social media compared to their Indian counterparts. It is observed that MNC pharmaceutical companies have been very active on various social media platforms, primarily Twitter, Facebook, and LinkedIn. They are also active on other platforms such as Instagram, Pinterest, and Flick to a certain extent, thereby ensuring a wider outreach to the community and society.

One of the plausible reasons for Indian companies not being so active on social media could be due to the lack of regulations regarding the use of social media for healthcare in India. Other reasons could be the investment cost, lack of user profiling, etc. Despite these shortcomings, it is important for Indian pharma companies not only to build up their presence on social media but be active on these platforms too. In order to ensure the authenticity of data, the companies can focus on getting their accounts verified so that the audience is assured of the accuracy and veracity of information. Since social media offers an opportunity to reach and connect, companies can reach out to the community including patients.

Even in terms of social media platforms, the number of followers and users among Indian pharmaceutical companies is low compared to international companies. Through verification of social media channels, especially on Twitter and Facebook, a higher activity on the social media channels, an increasing number of followers, as well as a higher interaction with the users can be achieved. Even patients and healthcare providers can easily reach out to the companies on Facebook and Twitter and to communicate companies can respond quickly by answering a query.

Since Instagram is the fastest-growing social media channel, companies should also try to increase their presence on this channel. It is also important to get a verified account on this platform. International companies can be taken as an example of how the accounts must be structured to reach a high number of followers. It is also very important to publish content that is interesting for the public so that the users have an incentive to follow the company on their social media channels.

Pharmaceutical companies must also be careful about what information they post on their social media accounts and on the internet. In the absence of verified accounts, it could set a wrong precedent and fake accounts can spread misinformation, which can negatively impact the image of the company. Another important issue when using social media without verification is problems that can arise due to privacy controls. Verification ensures that the data is protected to a great extent, the risk of data misuse is minimized, and the users get correct and reliable information (George et al., 2013). Thus, companies can counteract the influence of wrong information, which might falsely be communicated using an unverified or fake account (Greene & Kesselheim, 2010).

Since direct-to-consumer advertisement of prescription medicines is prohibited in India, pharmaceutical companies cannot advertise or promote their drugs using mass media including social media. However, social media can be an important tool for Indian pharmaceutical companies to educate people about healthcare. The government should also bring in regulations that help companies and communities understand the responsible use of social media for healthcare information. These regulations shall be such that they facilitate the use of social media by pharmaceutical companies while ensuring the safety of patients.

Our study had a few limitations. We carried out an analysis of the social media use of only the top 25 multinational and Indian pharmaceutical companies. A larger sample could be used to understand the use of social media by pharmaceutical companies in a better way. Another limitation is that in the case of the top 25 Indian pharmaceutical companies, subsidiaries of MNC companies such as GSK, Pfizer, Sanofi, and Novartis are also involved and hence they were excluded from analysis while studying Indian companies to reduce bias and error. Another limitation was we were not able to ascertain and verify the authenticity of social media platforms for Indian companies as most of them do not have a verified account. Since data was captured only till the end of September 2018, a few numbers with respect to posts, tweets, and likes, followers might have changed. The analysis does not study which is the best social media channel to be used by pharmaceutical companies.

Conclusion

Social media could be an important tool to educate patients about healthcare. It was observed from the study that multinational pharmaceutical companies are high users of social media in order to reach out to the community compared to Indian pharmaceutical companies. Many Indian pharmaceutical companies are either not present on social media or are not active. Only a few Indian companies have their verified accounts on some of these social media platforms. Further, only a few social media platforms like Twitter, Facebook, and LinkedIn are explored extensively by companies in comparison to Instagram, Pinterest, and Flickr.

Multinational organizations have consistently leveraged the use of social media and continue to do so in the evolving landscape. Social media channels are mostly used to disseminate information in India. With more than 200 million internet users and 130 million mobile internet users, Indian pharmaceutical companies can leverage the platform to communicate about health, healthcare, management of health and reach out to customers creating a direct communication channel. With the increasing use of mobile internet with new internet users being added due to its demographic dividend, India is poised to see a transformation in terms of social media used to reach out to healthcare information seekers, including providers and patients. Indian pharmaceutical companies can invest in being present on various social media platforms and evolving technologies with a focus on long-term growth.

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CHAPTER 12

Digital transformation of myopic retinopathy: insights from the Asian perspective

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Introduction

Myopia is the global public health issue among adults in the world, especially in East and Southeast Asia. Myopic retinopathy has become the leading cause for irreversible visual impairment (VI) and blindness in people of all ages, and its economic burden cannot be ignored (Hsu et al., 2004; Xu et al., 2006). According to recent metaanalyses conducted on study data, it is projected that the global prevalence of myopia will escalate to 50% by the year 2050. Additionally, these analyses indicate that the prevalence of high myopia within the global population will also rise to 10% (Holden et al., 2016; Ohno-Matsui et al., 2016). The ensuing VI will impose significant social and economic burdens on both individuals and society as a whole. According to estimates, the present worldwide economic output decline attributable to VI caused by myopic retinopathy is projected to reach a staggering sum of US$600 million. Notably, East Asian, characterized by their large myopic populations, are anticipated to contribute significantly to this overall loss (Naidoo et al., 2019).

Definition of myopic retinopathy

The condition known as "pathological myopia" is associated with "high myopia." Nonetheless, it is important to note that there exists a notable distinction in the underlying classification of this disorder. The term "high myopia" pertains solely to an elevation in myopic refraction, while the term "pathological myopia" includes a range of pathological alterations in the fundus. These alterations include posterior staphyloma, diffuse chorioretinal atrophy, and more severe myopic maculopathy (Ohno-Matsui et al., 2015). In 2015, a comprehensive study known as META-analysis for pathologic myopia (META-PM) developed a classification and grading system for myopic maculopathy. These lesions were divided into different grades, namely grade 0 for no

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myopic retinal degenerative lesion, grade 1 for tessellated fundus, grade 2 for diffuse chorioretinal atrophy, grade 3 for patchy chorioretinal atrophy, and grade 4 for macular atrophy. Additionally, three other lesions were identified, including lacquer cracks, myopic choroidal neovascularization, and Fuchs spot (Ohno-Matsui et al., 2015). According to this classification, pathological myopia is characterized by the presence of myopic maculopathy of grade 2 or above, the presence of "plus" symptoms, or the occurrence of posterior staphyloma. Ruiz-Medrano et al. (2019) conducted a classification of macular lesions associated with myopic maculopathy. The classification involved categorizing the lesions into three primary components: atrophic component (A), tractional component (T), and neovascular component (N). The proposed grading system incorporates lesion data obtained from both the patient's fundus photography and optical coherence tomography (OCT) image. Additionally, it incorporates structural alterations in the macula caused by traction, including macular schisis, macular detachment, and macular hole.

Epidemiology of myopic retinopathy

Asia and Western populations

The prevalence of high myopia is associated with the general prevalence of myopia. Therefore, in regions characterized by an increased prevalence of myopia, there will be a corresponding increase in the prevalence of high myopia and pathological myopia. pathological myopia has the potential to cause substantial VI in a considerable proportion of individuals, hence exerting a significant adverse influence on society. There exists a positive correlation between the degree of myopia and the chance of developing pathological myopia. The prevalence of pathological myopia among individuals with low to moderate myopia ranges from 1% to 19%. Nevertheless, individuals with extreme myopia may exhibit a prevalence rate ranging from 50% to 70% (Gao et al., 2011; Healey et al., 2007; Vongphanit et al., 2002). According to the findings, there is a positive correlation between the increase in myopic refractive error by 1D and the corresponding rise in the likelihood of developing pathologic myopia, with the latter increasing by 67% (Bullimore & Brennan, 2019).

The prevalence of myopic retinopathy in individuals of middle-aged and elderly populations is estimated to range from 0.9% to 3.1%, surpassing the prevalence of myopic retinopathy in children and adolescents, which is less than 0.2% (Wong & Saw, 2016). In general, there is a larger prevalence of myopic retinopathy in the Asian region, particularly in China, compared to European and American countries. This observation aligns with the general prevalence of myopia and the trend in the prevalence of high myopia. Pathological myopia ranks as the second most prevalent factor contributing to VI among adults aged 65 and older in Taiwan (Hsu et al., 2004). Pathological myopia is a significant contributor to bilateral low vision in Japan, ranking as the third leading cause. Additionally, it is the predominant cause of unilateral blindness among individuals aged 40 and above (Iwase et al., 2006). Based on research conducted in the Rotterdam Study (Klaver et al., 1998), the Copenhagen City Eye Study (Buch et al., 2001), and the Los Angeles Latino Eye Study (Cotter et al., 2006), it has been determined that pathological myopia ranks as the third most prevalent cause of blindness in Western nations.

There is a substantial association between older age and longer axial length and the occurrence of pathologic myopia (Chen et al., 2012; Gao et al., 2011; Liu et al., 2010). According to the findings of Samarawickrama et al. (2011), the prevalence of myopic maculopathy throughout childhood is rather uncommon. The most prevalent manifestations of this condition were tilted disk, observed in about 37% of cases, and peripapillary β-atrophy, observed in approximately 39% of cases. Nevertheless, it has been observed that among individuals aged 40 and above who have high myopia, there exists a greater occurrence of posterior staphyloma (23%) and chorioretinal atrophy (19.3%) (Chang et al., 2013). According to a study conducted by Hayashi et al. (2010), it was found that 40% of individuals with high myopia have progression to myopic maculopathy within a span of 12.7 years. This development is predominantly characterized by the emergence of newly developed or expanded chorioretinal atrophy or lacquer cracks. In another 10-year study, Shih et al. (2006) reported that in addition to choroidal neovascularization or macular atrophy, coalescence of patchy chorioretinal atrophy leads to significant vision loss.

The Gulf region

In the context of the global myopia epidemic, it is evident that the Middle East is experiencing a notable delay in addressing this issue, especially in comparison to East Asian nations. The observed disparity can be attributed to both the ethnic variations present in the region and its unique economic landscape. The economic context of the region may have influenced the comparatively lower prevalence of myopia in relation to other global regions. According to previous research, there exists a strong correlation indicating that individuals who primarily engage in near-work or indoor activities have an increased susceptibility to developing myopia (Huang et al., 2015). Based on current observations, it appears that Middle Eastern countries may have a lower prevalence of risk factors associated with these activities. The metaanalysis conducted on the Middle East region revealed findings from the random effects model (Khoshhal et al., 2020). The data indicated that the prevalence of myopia among individuals aged 15 or below was 4%, while among those aged over 15, it was 30%. The prevalence of myopia among individuals aged 15 or below was 3.5% for males and 4.2% for females. The prevalence of the condition among individuals aged 15 years and older was 31.7% for males and 31.9% for females. According to the results obtained from the Dubai Eye Health Survey (Rabiu et al., 2023), it was determined that the prevalence of myopia among individuals aged 40 years or over in Dubai, specifically among Emiratis, was found to be 27.4%. The prevalence rate mentioned in the statement is consistent with the results obtained from a study done in the northern region of Saudi Arabia (Parrey & Elmorsy, 2019). Nevertheless, it is important to acknowledge that the rates observed in this study are significantly lower when compared to the findings reported in several previous population-based studies conducted on the adult demographic. The prevalence of myopia was reported to be 36.5% in the Iran-Yazd Eye Study (Ziaei et al., 2013), 42.7% in the Myanmar-Meiktila Eye Study (Gupta et al., 2008), and 38.9% in the Singapore Epidemiology of Eye Disease Study (Pan et al., 2013).

Detection and monitoring of myopic retinopathy

Bridging classic biometry with advanced optical coherence tomography techniques

Traditional diagnostic methods include ocular A-scan ultrasonography and intraocular lens (IOL) biometry. Saka et al. (2010) used ocular A-scan ultrasonography to examine 101 highly myopic patients (with a refractive error ≤ -6.0 D or axial length $\geq$ 26.5 mm), with an average follow-up of 8.2 years. They found that 31% of the eyes showed an axial growth of more than 1 mm (averaging 1.5 mm). In a separate investigation conducted by Saka et al. (2013), IOL biometry was employed to monitor 185 highly myopic patients (with a refractive error ≤ -6.0 D or axial length $\geq$26.5 mm) over 2 years. They observed that the average axial length increased from (29.35 ± 1.80) to (29.48 ± 1.85) mm. However, the limitation of the A-scan lies in the risk of cross-infection due to the contact nature of the probe. The IOL biometer has high requirements for the refractive medium and demands a high level of patient cooperation and fixation, which limits its application in clinical settings.

Research indicates that for adolescents, the presence of peripapillary atrophy (PPA) is a hallmark of myopia onset. Moreover, PPA is also associated with high myopia (Kim et al., 2012). Color fundus photography and OCT are vital tools for observing PPA. The genesis of PPA is attributed to the stretching of the posterior pole of the eyeball, which pulls the retinal pigment epithelium (RPE) layer, exposing the choroidal blood vessels not covered by the pigment epithelium. Takahashi's study (Takahashi et al., 2013) found that in eyes with high myopia, posterior staphyloma and axial length elongation not only cause thinning of the choroid, but also pull the choroid towards the base of the posterior staphyloma, resulting in enlargement of the PPA. This suggests that the progression of myopia may be clinically predictable by observation of changes in PPA morphology. PPA is classified into α-zone and β-zone based on color fundus photography (Jonas et al., 1989). PPA of the α-zone is characterized by irregular hypopigmentation and hyperpigmentation of the RPE. The β-zone PPA exhibits RPE and choriocapillaries degeneration, exposed sclera, and noticeable choroidal vessels situated between the optic disk and the α-zone (Jonas et al., 2013). Given that the boundary of the α-zone is relatively ambiguous, while the β-zone's boundary is more distinct, clinical observations using ophthalmoscopy or fundus photography yield inconsistent repeatability for the α-zone. Furthermore, some believe that the β-zone is the result of further damage to the α-zone. Therefore, more research focuses on analyzing the mechanisms of β-zone development and its associated influencing factors.

With the application of spectral-domain optical coherence tomography (SD-OCT), researchers have discovered that the previously observed β-zone through fundus images can be further divided into the β-zone and γ-zone on OCT (Fig. 12.1). The β-zone, referred to as PPA_{+BM} on OCT, encompasses the region extending from the endpoint of Bruch's membrane to the endpoint of the RPE. It is distinguished by the lack of the RPE layer on Bruch's membrane, substantial loss of photoreceptor cells, and obstruction of the choriocapillaris. The γ-zone, which is also known as PPA_{-BM} on OCT, encompasses the region extending from the periphery of the optic disk to the termination point of Bruch's membrane. It is characterized by the absence of Bruch's membrane, the lack of deep retina, occlusion of the choriocapillaris, and the exposure of the sclera (Kim et al., 2014). Research findings suggest that the presence of PPA is considered to be indicative of high myopia in adults (Akagi et al.,

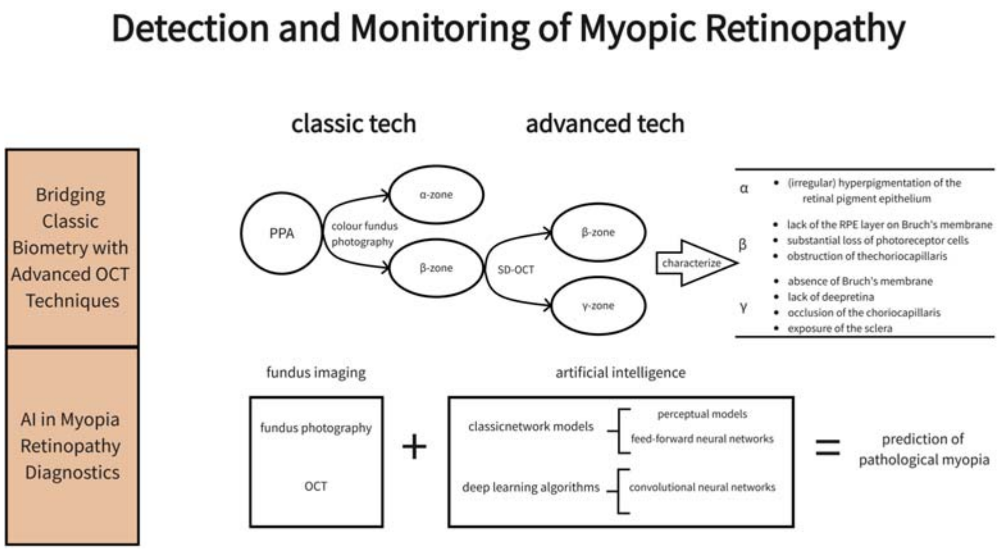

Figure 12.1 Integrating traditional and advanced technologies for the detection and monitoring of myopic retinopathy. *Figure created by Xuan-Yu Chen.*

2013; Jonas et al., 1988). The occurrence of PPA in adolescents is indicative of the onset of myopia(Kim et al., 2012; Samarawickrama et al., 2011). Zhang et al. (2018) randomly selected individuals with emmetropia and various refractive errors from the Beijing Eye study and analyzed their optic disk OCT images. In the emmetropic and total populations, the prevalence of β-zone was 68.8% and 72.2%, respectively, while the prevalence of γ-zone was 16.8% and 26.3%. The β-zone was mainly correlated with age and had a weaker association with axial length. In contrast, the γ-zone was significantly associated with axial length but not with age. These results suggest that factors such as age and axial length should be taken into account when investigating the relationship between the β-zone and glaucoma. The γ-zone is related to the onset and progression of retinal changes in high myopia.

Artificial intelligence in myopia retinopathy diagnostics

In recent years, the rapid advancement of machine learning algorithms has positioned them at the forefront of the artificial intelligence (AI) domain. Among these, computer neural network algorithms, which simulate the behavioral characteristics of biological neural networks, adjust inter-nodal relationships to conduct distributed parallel information processing. Progressing from perceptual models, feed-forward neural networks and other classic network models to the development of deep learning algorithms such as convolutional neural networks (CNNs), these algorithms allow multi-layered computational models to learn data across multiple abstract categories (Fig. 12.2). Therefore, the combination of medical imaging with AI can be taken as the most promising field of research. In terms of lesions, medical images are mainly concentrated on lung nodules (Tan, Zhou et al., 2021; Wang et al., 2019), lung cancer

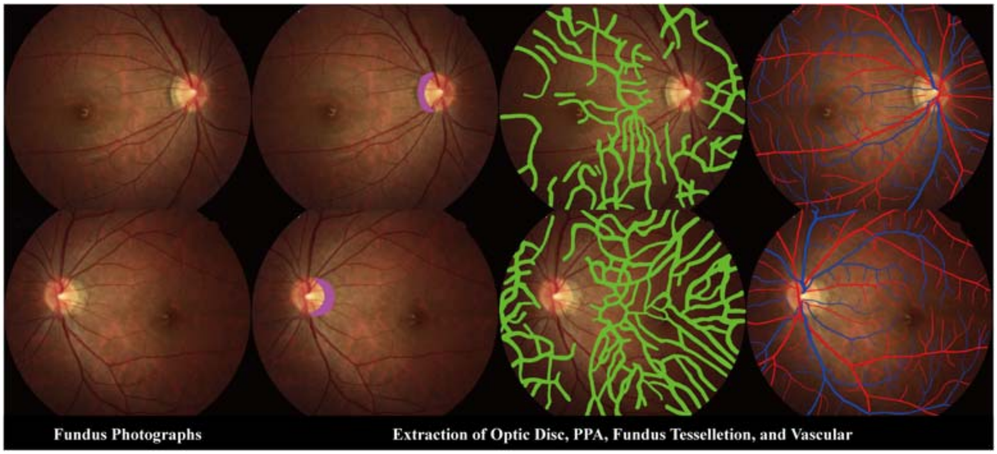

Figure 12.2 Application of artificial intelligence in fundus photograph analysis and vascular feature extraction. *Figure created by fundus image intelligent analysis software—EVisionAI.*

(Ardila et al., 2019; Kinoshita et al., 2023), brain (Brosch et al., 2016; Pereira et al., 2016), heart (Baessler et al., 2023; Zreik et al., 2018), thyroid (Buda et al., 2019; Yang et al., 2023), prostate (Le et al., 2017; Turkbey et al., 2013), liver (Hamm et al., 2019; Yasaka et al., 2018), eye (Gulshan et al., 2016; Kermany et al., 2018; Rajesh et al., 2023; Ting et al., 2017), and breast (Mahmood et al., 2020; Shihabuddin & K, 2023).

The most commonly used AI-based diagnostic techniques for high myopia imaging are fundus photography and OCT, both of which are noninvasive and suitable for routine follow-up eye examinations (Zhang et al., 2022). Pathological myopia is a major cause of VI. It is currently unclear whether pathological myopia progresses in parallel with myopia itself, and the underlying mechanism remains undetermined. Early detection of pathological myopia in myopic individuals is of paramount importance in the prevention of VI and blindness (Ohno-Matsui et al., 2021). Numerous studies have been conducted on predicting pathological myopia based on fundus imaging. Wan et al. (2021) proposed a supplementary diagnostic algorithm based on a deep convolutional neural network (DCNN) to classify fundus images into three distinct categories: normal fundus, low-risk high myopia, and high-risk high myopia. The area under the curve (AUC) for those with low-risk high myopia was determined to be 0.9968, while for those with high-risk high myopia, the AUC was found to be 0.9964. Li et al. (2022) trained four distinct CNN models on macular OCT images to identify retinoschisis, macular hole, retinal detachment and pathological myopic choroidal neovascularization resulting from pathological myopia. The models achieved impressive AUC values, ranging from 0.961 to 0. 999. Tann Anees et al. (2021) developed a deep-learning algorithm based on fundus photographs to detect myopic retinopathy. A total of 226,686 retinal pictures were utilized in the development process. The algorithms demonstrated an AUC of 0.969 or higher for myopic macular degeneration and 0.913 or higher for high myopia. The safety and practical application efficacy of the data were assessed by comparing them with the evaluations of six expert graders. It has the potential to serve as an effective tool for large-scale global myopic retinopathy screening.

Telemedicine and remote diagnosis

Advancements in telemedicine and artificial intelligence integration in ophthalmic care

Telemedicine originally centered on cross-regional consultations between physicians, epitomizing Internet-based medical models. Meanwhile, eHealth prioritizes a patient-centric service approach, emphasizing individual health records. With the rise of smartphones and tablets, "mHealth" (mobile health) emerged as a concept. The advent and proliferation of wearable tech further enable real-time monitoring of personal health indicators, fostering the notion of "Connected Health." This promotes patient engagement and self-care (Weinstein et al., 2018). "Coordinated care" encompasses a spectrum of services from prevention to follow-up visits. It involves various stakeholders, from hospitals to family members, aiming to holistically integrate objectives like accessibility, safety, efficiency, and user satisfaction (Mcdonald et al., 2007). Ophthalmology occupies a prominent position in the field of healthcare advances due to its distinct attributes. Many diagnoses of eye diseases heavily rely on developments in imaging and surgical techniques. This has led to the increased utilization and expansion of telemedicine and AI in ophthalmic care. Numerous studies have confirmed the dependability and effectiveness of telemedicine in the screening and diagnosis of ocular diseases. The field of teleophthalmology consultations is experiencing significant growth, driven by advancements in surgical robots and navigation technologies. This growth presents substantial opportunities for the expansion of remote ophthalmic surgery (Grau et al., 2019; Parikh et al., 2020).

Telemedicine screening, particularly for conditions such as diabetic retinopathy (Dr), has been adopted globally as a cost-effective and comprehensive approach to public eye health. The United Kingdom (Scotland et al., 2010) and Singapore (Nguyen et al., 2016) were among the pioneering nations to implement telemedicine-based Dr screening. This approach involved the utilization of healthcare professionals who possessed specialized training in digital fundus photography to conduct imaging and interpretation. Following that, the United States, India, Australia, South Africa, Zambia, and Tanzania have also commenced tele-screening programs for Dr with differing degrees of implementation. In 2010 Singapore launched a statewide telemedicine-based Dr screening program. This initiative covered approximately 200,000 diabetic patients, with fundus photographs collected from 18 primary healthcare institutions across the nation. These images were then interpreted by physicians trained in medical image analysis. Compared to traditional in-person evaluations, the tele-screening approach yielded direct cost savings of 144 Singaporean dollars per patient (Nguyen et al., 2016). Recent advancements have seen the incorporation of deep learning systems for Dr and associated ophthalmic conditions into Singapore's integrated Dr program, marking it as a pioneering national effort in AI-assisted image interpretation (Ting et al., 2017). Beyond Dr, tele-screening and AI technologies are significantly impacting other ophthalmological areas. For retinopathy of prematurity (ROP), telemedicine offers efficient and economical screening with minimal risk to the premature infant's overall health (Brady et al., 2020). India, with its high prevalence of premature births, has successfully launched ROP tele-screening initiatives, including the Karnataka State's ROP Internet-Assisted Diagnosis System and the ROP Eradication Save Our Sight project (Campbell et al., 2021; Shah et al., 2018).

In Asia, there has been notable implementation in China. Between 2008 and 2009, the Beijing Institute of Ophthalmology launched the Beijing Eye Public Health Care Project. This initiative aimed to screen all elderly individuals aged 55 to 85 years in the rural regions of Greater Beijing. Using a telemedicine approach to cover a population of approximately 3.5 million, the institute successfully developed and implemented a mass screening system reaching 80% of the target demographic. The total cost for this project amounted to approximately 1,800,000 Yuan, equating to 3.20 Yuan (roughly US$0.50) per participant. The findings underscored the importance of including screening not just for cataracts, but also for prevalent blinding eye conditions such as glaucoma, AMD, and Dr. This initiative served as a foundational step towards establishing a telemedicine-based public health care system for ophthalmology in China (Xu et al., 2012). The implementation of an AI-based tele-screening system for diabetic Dr has been carried out by the Guangzhou Zhongshan Ophthalmic Center in conjunction with two urban endocrinology departments, namely St Vincent's Hospital in Melbourne and University Hospital Geelong, Barwon Health, both located in Australia. After careful assessment, the system demonstrated a sensitivity of 92.3% and a specificity of 93.7% in accurately identifying and referring cases. Furthermore, an investigation into patient satisfaction was conducted using a survey to assess their perceptions of AI telemedicine. The findings indicated that a significant majority of respondents, specifically 96%, expressed pleasure or high levels of satisfaction with the AI tele-screening process (Keel et al., 2018). Furthermore, the Beijing Peking Union Medical College Hospital employed a remote consultation platform based on fifth-generation(5G) technology, in conjunction with real-time laser photocoagulation, to provide remote ophthalmic treatment to patients with Dr who were selected from the Huzhou First People's Hospital in Zhejiang Province, China. The distance between the two hospitals was approximately 1200 km. The findings indicated that the implementation of all treatment protocols proceeded seamlessly, with no occurrence of any negative events during the photocoagulation procedure. The mean ($\pm$ SD) network latency time was 20 ($\pm$ 3) milliseconds, and there were no statistically significant occurrences of signal loss or indications of image buffering or pixelation. The average ($\pm$ SD) duration of the video consultation was 23.4 ($\pm$ 5.6) minutes, of which treatment planning took up 3.5 ($\pm$ 1.1) minutes, and the automatic laser procedure lasted 18.1 ($\pm$ 5.2) minutes for each eye. This enabled ophthalmologists from both geographical sites to effectively collaborate in delivering accurate and prompt treatment and care for patients with Dr (Chen et al., 2021).

Challenges in teleophthalmology

The growing demand and utilization of ophthalmic telemedicine are driven by the rapid progress in AI and telemedicine technologies. However, there are also several notable concerns that are primarily evident in the following aspects.

Limitations in emulating traditional eye examinations

While fundus photography serves as a tool for screening retinal disorders, it often falls short of delivering clear images of the peripheral retina, leading to potential misdiagnoses of certain retinal conditions. Additionally, slit-lamp biomicroscopy remains unfeasible through video consultation platforms, and the nuanced, dynamic evaluations provided by clinicians during anterior segment imaging are not easily replicated. Consequently, a thorough diagnosis and treatment approach for specific ocular conditions, like uveitis, becomes problematic within the telemedicine framework.

Infrastructure and staffing constraints

The effective implementation of remote medical services hinges on robust infrastructure, including imaging equipment, hardware facilities, and Internet technology. Tools such as nonmydriatic cameras, OCT, and smartphone-adaptable fundus cameras entail considerable investments. The training required for primary care staff to adeptly manage these devices not only amplifies their workload but also elevates their stress levels. Due to various socio-geographic factors, specific regions or patient groups might lack essential network and communication resources, resulting in telemedicine inadequacies. Moreover, VIs can restrict some patients from efficiently navigating certain digital platforms, limiting the scope of ophthalmic teleconsultation (Li et al., 2021).

Physician's duty and associated risks

While numerous studies underscore the pivotal role of ophthalmic telemedicine in screening and tracking conditions like Dr, ROP, glaucoma, and AMD, the qualitative experience of telemedicine often pales in comparison to traditional face-to-face interactions. 59% of ophthalmologists convey reservations about basing decisions solely on ophthalmic imagery (Rathi et al., 2017). Current protocols involve transparent communication about the pros and cons of telemedicine, ensuring patients' understanding, and obtaining informed consent. Still, rigorous prospective research is imperative to mitigate misdiagnoses, errors, and minimize potential risks in telemedicine.

Influences on patient reception and satisfaction in telemedicine

The effectiveness of telemedicine and subsequent patient satisfaction have been intrinsically linked to the educational and cognitive backgrounds of the patients, especially concerning disease diagnosis and continued monitoring. The study conducted by Wildenbos et al. (2018) examined the influence of age on the utilization of telemedicine, specifically focusing on those aged 50 and above. The researchers identified several factors that contribute to the effectiveness of telemedicine in this age group, including cognitive function, motivation, physical capabilities, and perceptions.

Cybersecurity and privacy implications

The surge in telemedicine adoption brings to the fore concerns regarding cybersecurity and privacy, encompassing ethical, legal, and regulatory dimensions. Telemedicine transcends a mere procedural approach, morphing into a sophisticated diagnostic and therapeutic process, necessitating cohesive collaborations across various disciplines, from medical to administrative sectors. Therefore, crafting and enforcing pertinent laws, regulations, and guidelines are paramount for its streamlined and ethical application.

Tackling myopia: global initiatives and China's strategic approach

Myopia, identified as a paramount public health concern worldwide, has garnered extensive global attention. East and Southeast Asia, encompassing China, are hotspots for myopia prevalence. To adeptly navigate and mitigate the ongoing progression of myopia, a synergistic approach is essential, drawing on the expertise of ophthalmologists, optometrists, community physicians, school health professionals, and parents. Central to this endeavor are the standards set by vision care professionals and researchers. The International Myopia Institute (IMI), initiated under the leadership of Professor Holden from the Brien Holden Vision Institute in Sydney, Australia, is structured with diverse subspecialty groups. It has promulgated a series of seminal white papers in a special segment of Investigative Ophthalmology & Visual Science, providing cogent guidelines on universal definitions, innovative diagnostic modalities, and therapeutic strategies for myopia (Wolffsohn et al., 2019).

China has also introduced white papers, guidelines, and expert consensus documents pertaining to the prevention and management of myopia (Chinese Optometric Association et al., 2022; Public Health Ophthalmology Branch of Chinese Preventive Medicine, 2023). In 2018, the Ministry of Education and other seven ministries and commissions issued the Implementation Plan of the Myopia Prevention and Control for Children and Adolescents (China, 2018), indicating myopia control has become a national strategy. The implementation plan states that by 2030, the prevalence of myopia should be reduced to around 3% in children aged 6 years, less than 38% in primary school students, less than 60% in junior high school students, and less than 70% in senior high school students. With the rising prevalence of high myopia among adolescents in China and its progressive emergence as a prominent factor contributing to irreversible blindness. To address this challenge, a high-quality big data platform is necessary. We have launched a major research initiative called the China Alliance of Research in High Myopia (CHARM). The CHARM consortium is a recently formed collaboration comprising over 100 hospitals and institutions nationwide. Its primary objective is to facilitate collaboration and promote data sharing in the areas of high myopia screening, classification, diagnosis, and therapeutic development (Zibing et al., 2023).

Novel therapeutic approaches for high myopia

Present therapeutic strategies for high myopia largely include traditional spectacle correction, refractive corneal surgery, and posterior chamber phakic IOL implantation. These approaches focus on addressing myopia from a refractive perspective, providing methods for correcting visual acuity. However, they do not effectively reverse high myopia. However, the management of high myopia from an axial perspective may provide a potential opportunity for true reversal. As a result, the concept of "axial modulation" has arisen as an innovative therapeutic objective for the treatment of high myopia (Fig. 12.3).

Repeated low-intensity red light therapy

Red light is distinguished by its wavelength, which falls within the range of 600–700 nm (Huang et al., 2022). Due to its significant impact on mitochondrial function, it has been widely employed in the clinical treatment of several medical disorders (Austin et al., 2022). In recent years, RLRL irradiation has been recognized as a novel treatment method for inhibiting the rapid progression of myopia in children (Jiang et al., 2022). The RLRL

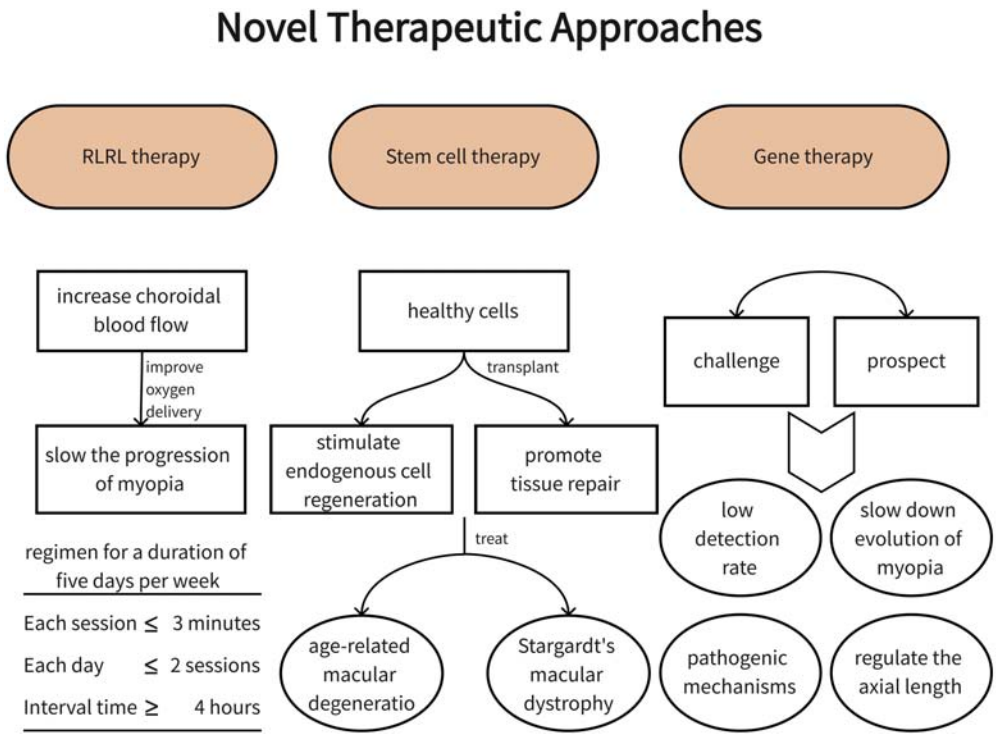

Figure 12.3 Emerging therapeutic strategies for myopic retinopathy. *Figure created by Xuan-Yu Chen.*

procedure, as recommended by experts, involves administering treatments when the pupil is in its natural form. Each session should not exceed 3 minutes and individuals should not exceed two sessions per day. It is important to maintain a minimum of 4 hours between each treatment. It is recommended to follow the regimen for a duration of five days per week (For & Adolescents, 2022). Although the exact mechanism responsible for the progression of myopia in children and adolescents is not fully understood, it has been hypothesized that the use of RLRL may increase choroidal blood flow. This, in turn, may improve oxygen delivery to the sclera and facilitate beneficial changes in the scleral extracellular matrix. Consequently, this process may help slow the progression of myopia (Hung et al., 2018; Zhou et al., 2022). Currently, the majority of RLRL clinical studies typically include a follow-up period ranging from 1 to 2 years (Xiong et al., 2022; Xiong et al., 2023). Pediatric patients undergoing this treatment consistently demonstrate a deceleration or reduction in the growth of the axial length. A small proportion of participants chose to discontinue their participation in the RLRL studies. This decision was primarily due to either not following the prescribed treatment plan or selecting alternative treatments such as orthokeratology. Additional discontinuations occurred as a result of unrelated systemic conditions, including allergic rhinitis, dental caries, and influenza. The potential side effects of RLRL are currently being evaluated over an extended period of time. According to expert consensus from 2022, it is recommended to discontinue RLRL irradiation in patients who exhibit prolonged afterimages, acute severe visual acuity decline, persistent halos, dark spots, or any abnormalities in retinal structure and function after treatment (For & Adolescents, 2022).

Stem cell therapy for myopic maculopathy

Cell therapy represents a pioneering approach that utilizes the transplantation of healthy cells into the body, aiming to stimulate endogenous cell regeneration and promote tissue repair (Golchin & Farahany, 2019). There have been notable advancements in stem cell-based interventions for retinal diseases. Specifically, in 2012, Schwartz et al. (2012) pioneered the use of RPE cells, derived from human embryonic stem cells, to treat conditions like age-related macular degeneration and Stargardt's macular dystrophy. Building on this, Mandai and colleagues in 2017 (Souied et al., 2017) successfully transplanted RPE cells generated from induced pluripotent stem cells (iPSCs) into patients diagnosed with exudative AMD, showcasing the potential of iPSC-derived therapeutic cells. Validating the clinical utility of this approach, several studies have affirmed the safety of transplanting RPE cells that are differentiated from stem cells into retinal tissues. A seminal study by Zhang et al. (2021) involved the transplantation of human iPSC-RPE cells, compliant with Good Manufacturing Practice (GMP) standards, into a murine model of retinal degeneration. Subsequent to the transplantation, there was discernible pigment deposition at the site of implantation in the mice, and more importantly, a pronounced enhancement in their visual function, as evidenced by retinal electrophysiological tests. This pivotal research solidifies the promise and safety profile of human iPSC-RPE cell transplantation in addressing retinal degenerative conditions.

During the progression of myopia, RPE cells are particularly vulnerable, experiencing both atrophy and apoptosis. Analogous to various retinal degenerative disorders, the compromise of RPE cells often precipitates the subsequent degeneration of photoreceptor cells, a manifestation that is especially pronounced in cases of myopic maculopathy. The clinical assessments often fail to adequately recognize the importance of RPE cell in cases of high myopia. In the specific case of macular holes caused by high myopia, surgical procedures such pars plana vitrectomy (PPV) have demonstrated efficacy in repairing the hole and repositioning the retina. However, it is important to note that the visual outcomes following the surgery may not consistently meet the expected standards (Zhang et al., 2017). Macular atrophy, which occurs as a consequence of PPV, often becomes evident during the 1−4-month period following surgery. This condition is defined by the presence of localized RPE atrophy underneath the center of the fovea, as well as disturbances in the Bruch's membrane (Fang et al., 2020). Over a period of time, the degenerative pattern gradually becomes more severe, resulting in extensive atrophy that affects both the retina and choroid. The significance of RPE cells in the development of myopic macular degeneration is of utmost importance. The utilization of RPE cells produced from stem cells presents a compelling scientific approach with potential therapeutic implications, thereby potentially leading to notable breakthroughs in clinical practice (Ma et al., 2022).

Gene therapy for high myopia

The onset and progression of myopia result from a complex interplay of genetic and environmental influences. Recent investigations have identified several causative genes associated with high myopia (Cai et al., 2019), marking a substantial leap in our comprehension of the disease. Nevertheless, the field of high myopia genetics is riddled with challenges. One major concern is the relatively low detection rate of these identified genes within the high-myopia population; only approximately 25% of those with high myopia reportedly possess some of these genes. In addition, the specific pathogenic mechanisms by which these genes cause high myopia remain largely unknown. Prevailing theories postulate that these genes may affect retinal energy metabolism, alter photoreceptor cell functionality, or alter scleral composition (including elements such as extracellular matrix, elastic fibers, and collagen fibers). However, a complete understanding of these molecular pathways is still in the future.

In the context of gene therapy research, it is imperative to direct efforts towards targeting tissues that are specifically affected by pathogenic genes in the case of high myopia. The current study highlights the significant contributions of the neuronal retina and sclera in the initiation and advancement of myopia. Several genes, including the BSG gene, have been found to be involved in the expression of several ocular areas, such as the RPE, neural retina, and ciliary body (Jin et al., 2017). Hence, it is plausible that the RPE, neuronal retina, and ciliary body play a crucial role in the progression of myopia. Through the utilization of adenoviral vectors, it is possible to strategically administer the corrected gene to these specific organs, with the intention of achieving normalization or modulation of gene expression. This concept not only presents a possible approach to slow down the evolution of myopia, but also suggests a way for regulating the axial length bidirectionally by modulation of gene expression.

Conclusions and future perspectives

The convergence of medicine and technology in the field of ophthalmology is evident in the digital transformation of myopic retinopathy. The escalating global prevalence of myopia has led to a growing need for efficacious approaches to the identification, surveillance, and management of this condition.

Key conclusions

1. The epidemiology of myopic retinopathy indicates a significantly greater frequency in Asia, specifically in China, when compared to European and American populations. In contrast, the Middle East exhibits a discernible delay in effectively tackling the worldwide myopia pandemic.
2. Contemporary technologies, namely OCT, have assumed a critical role in the identification and surveillance of myopic retinopathy. These techniques are particularly valuable in assessing the advancement of PPA and its association with high myopia.
3. The utilization of deep learning and neural networks in AI diagnostic methods for myopic retinopathy has demonstrated significant promise in the context of extensive screening efforts.
4. The integration of telemedicine and remote diagnosis is rapidly becoming a crucial aspect of public eye health, however, accompanied by inherent technical and implementation obstacles.
5. Current therapeutic options predominantly prioritize the correction of myopia through refractive techniques. However, there are developing treatments, including red-light therapy, stem cell therapies, and gene therapies, that hold promise for potentially achieving a true reversal of high myopia.

Future perspectives

With the rising incidence of myopia and its more severe variant, high myopia, there's a growing concern about its early onset and the consequent surge in prevalence. This trend has positioned it as a primary contributor to low vision and irreversible blindness, particularly among younger and middle-aged cohorts. Accurately distinguishing between high and pathological myopia is critical. Embracing advanced technologies, like AI, is essential for effective screening and preventive strategies. Furthermore, interdisciplinary collaborations can enhance genetic screenings for early-onset myopia and introduce innovative therapeutic modalities.

This article provides an in-depth examination of how digital transformation is reshaping the approach to tackling myopic retinopathy, with a focus on the nuances of the Asian demographic. Asia is experiencing a significant increase in the incidence of myopia, particularly among the young. The World Health Organization (WHO) strategy for the prevention of blindness provides a robust global framework that emphasizes the importance of early detection and prompt action. AI-enabled diagnostic tools are gaining ground in primary healthcare settings worldwide, with significant potential to improve diagnostic accuracy and disease surveillance efficiency. In line with the WHO Eye Care Competency Framework (ECCF), we are advocating for a number of targeted policy initiatives: The adoption and integration of electronic health records with AI analytics is paramount. This synergy will streamline retinopathy risk assessment in community and primary care settings, thereby increasing efficiency. In addition, educational programs to equip healthcare professionals with digital skills are essential. These should include comprehensive training in advanced imaging and data analysis to enhance their skills. Addressing regional development disparities is essential; policy formulation should focus on resource-poor regions, with solutions developed through collaborative ventures involving governments and nongovernmental organizations.

In the current healthcare paradigm, ophthalmic telemedicine, although promising, primarily serves as an adjunct to traditional consultations. Challenges related to infrastructure, staffing, medical risks, patient acceptance, and data security remain. However, the rapid advancements in AI, combined with the proliferation of 5G communication networks, herald a transformative phase. With standardized training for primary healthcare providers and the establishment of relevant regulatory frameworks, the scope of ophthalmic telemedicine is set to expand. It promises comprehensive management of chronic ophthalmic conditions, timely consultations, and even the potential for remote surgical interventions, ensuring consistent, high-caliber, and sustainable patient care.

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CHAPTER 13

Healthcare travel resilience through digital healthcare adoption: lessons from Malaysia during the COVID-19 pandemic

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Introduction

The World Health Organization (WHO, 2018) defined digital health as the "field of knowledge and practice associated with the development and use of digital technologies to improve health." However, Meskó et al. (2017) offered a more nuanced perspective, framing it as "the cultural transformation of how disruptive technologies providing digital and objective data lead to an equal doctor-patient relationship with shared decision-making and the democratization of care."

The healthcare industry is currently undergoing a substantial transformation driven by artificial intelligence (AI), blockchain, and cloud computing (McGinnis et al., 2021; Wong & Sa'aid Hazley, 2020). Digital health technologies, encompassing mobile phones, electronic health records (EHRs), and wearables, are reshaping the understanding of health behavior, emphasizing informed decision-making, cost reduction, and improved customer engagement. These technologies not only enhance patient experiences but also offer benefits to service providers by reducing costs, facilitating information exchange, minimizing errors, and managing supply and demand.

Real-time interventions are facilitated through integrative platforms, breaking down physical barriers and enhancing education and awareness among patients. Online communities contribute significantly to patient engagement (Pagoto & Bennett, 2013). In fact, the recent COVID-19 pandemic has highlighted the value of digital technologies in healthcare, addressing service overutilization through the widespread adoption of digital solutions, including health tracking applications (OECD, 2020; Zeadally et al., 2020). Despite embedded safeguards, concerns about privacy and cybersecurity have been raised.

Postpandemic, studies underscore the continued use of digital health in managing healthcare systems (D'Anza & Pronovost, 2022; Sindhu, 2022). Countries like India have adapted tracking applications for various purposes, repurposing its application for

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general healthcare management. However, the transformation of digital health's value varies across countries, influenced by the unique needs of different stakeholders. Telehealth encompassing telemedicine prescribing and remote patient monitoring, is eliminating geographical restrictions, ensuring timely access, and shaping the ongoing evolution of digital healthcare. Perhaps, anticipated further advancements will unfold as technology continues to evolve.

The evolution from traditional to the digital healthcare system

Healthcare 4.0 is a digital revolution driven by data and intelligence, utilizing the Internet of Things (IoT) and wireless networks. It emphasizes patient needs and individualized treatment, with systems for recommending healthcare becoming key components. The road map that takes healthcare from a traditional to a digitalized version highlights the various technological sectors that help with digital transformation (Sharma et al., 2023). The global landscape has grappled with deadly diseases like SARS and Ebola, prompting adaptations in healthcare management. The evolution from traditional to digital healthcare represents a paradigm shift in the delivery and management of healthcare services. For instance, the integration of new technologies, particularly digital tools and monitoring systems, has revolutionized surveillance and intervention strategies. The transition has been facilitated by advancements such as EHRs, telemedicine, and wearable devices.

In the realm of digital health, there has been a profound shift in healthcare service dynamics, moving from a traditional face-to-face model to one that prioritizes prevention alongside cure, influenced by consumerism. This paradigm shift, empowered by disruptive technologies, challenges healthcare providers to transcend traditional roles and accommodate the rise of informed customers (Zimlichman et al., 2021). For example, the adoption of EHRs has enhanced information accessibility, streamlined communication, and improved patient outcomes (Adler-Milstein et al., 2017). Patient survival rose as a result of scientific and technological advancements and digitalization. Due to a lack of technological capabilities and competition, doctors could not communicate with one another in the past. Additionally, affirmative action in medicine was nonexistent. The high cost of services results from doctors performing unnecessary testing and the lack of oversight over their pricing practices (Ahmad et al., 2022).

Additionally, the widespread use of telemedicine, as noted by Bashshur et al. (2016), has increased remote access to medical consultations, particularly crucial during global health crises. This evolution not only enhances efficiency but also promotes patient-centered care. As healthcare continues to digitize, ongoing research and innovative solutions will be essential to address challenges and ensure the ethical and secure implementation of digital technologies in the medical domain.

Disruptive technologies, introduced with the potential to reduce costs and enhance services, have triggered a paradigm shift in the healthcare industry (Franklin, 2021). Despite some resistance from downstream service providers, innovations like EHRs, online consultations, and mobile applications have streamlined operations. The preventive approach, adopting a customer-centric focus, allows for customization to enhance the patient experience. IR 4.0 technologies such as AI, the IoT, and machine learning not only contribute to improving processes, diagnosis, and monitoring but also shape the landscape of digital health.

Despite the recent COVID-19 pandemic caused severe economic disruptions, it also accelerated the adoption of digital health, prompting a shift to alternative platforms like telemedicine to reduce physical visits to hospitals. This transformation was crucial for mitigating transmission, rendering manual contact tracing impractical. However, concerns about the potential marginalization of individuals lacking literacy or technological proficiency have been raised (Meskó et al., 2017). In this instance, the government plays a pivotal role in ensuring universal healthcare accessibility and rectifying constraints to prevent adverse effects on interventions.

Currently, digital health technology is in a growth stage, evident in its integration for the improvement of the healthcare system. Meskó et al. (2017) characterize the shift from traditional to digital healthcare as a "cultural transformation." The accelerated transition during the pandemic holds promise for the future of digital health, contingent on collaborative efforts from stakeholders to enhance the healthcare ecosystem. The current trajectory prioritizes health and wellness, influenced by increasing advocacy for health-conscious practices, shaping the offerings of service providers. While the evolving landscape presents opportunities, stakeholders must remain mindful of ongoing technological advancements.

The growth and trend of digital healthcare in Asia

According to Baur et al. (2021), due to limited legacy health infrastructure, rising consumer expectations, changing demographics, and technology advancements, Asia is well-positioned for fast changes in the healthcare industry. When taken as a whole, these elements allow governments, healthcare providers, and consumers to rethink the administration and delivery of healthcare completely. These advancements are causing consumer-focused digital health ecosystems to spread across Asia at a pace and scale never seen before. The impact of digital health extends to more than a billion individuals, with projections indicating that by 2025, the total value of digital health in Asia could reach a substantial $100 billion, marking a significant increase from the $37 billion reported in 2020 (Baur et al., 2021). In Asia, people are becoming more conscious of EHRs and its significance. Sensitive patient data is protected via methods that are effectively implemented by many hospitals and healthcare systems. However, because healthcare data has such a high value, securing it requires sophisticated technology and a compliance-driven approach (Kandasamy et al., 2022).

Due to digitization, Asian markets will probably be able to collect and analyze healthcare data more efficiently than Western systems (Baur et al., 2021). As per the Future Health Index (2019), clinical physicians and other medical professionals use Chinese digital technology for treatment at remarkably high rates. In China, 94% of medical professionals utilize apps for digital health, with an average of 78% across 15 nations, including the United States and certain Asian countries (Yeganeh, 2019). Hence, the healthcare industry is expected to be very dynamic and fast-evolving worldwide, characterized by influences such as globalization, economic uncertainty, social upheaval, demographic shifts, and technological innovation. However, there are difficulties in the development and implementation of digital healthcare technology to support patient-centered care; steps must be taken to improve digital literacy as it is a significant barrier to patients and healthcare professionals' (HCPs) adoption of these technologies and, if left unchecked, may limit access to patient-centered healthcare. It follows that instruction in digital literacy is necessary (Kosowicz et al., 2023).

Precision medicine is growing along with digitization, with advancements in analytics, and genomics sequencing paving the way for personalized medicine that develops therapies for a patient's unique genetic profile and lifestyle. Personalized medicine aims to enhance overall illness prevention, diagnosis, and treatment by considering a patient's environment, genes, and lifestyle (Yeganeh, 2019). The combined yearly growth in regional health spending among Asian nations is over 7%, significantly higher than that of Western Europe and North America.

A comprehensive poll of pharmaceutical manufacturers' executives revealed that 39% still view China as their primary market, compared to 22% who view Japan as their primary market, considering the existing revenue sources from branded medications relative to generics (L.E.K., 2019). In general, hospitals and outpatient care in the ASEAN region still need to widely utilize medical devices, which presents enormous opportunities for market expansion and growth (Hidayati et al., 2021).

Nevertheless, it is crucial to highlight that Japan maintains its status as the leader in medical technology growth in Asia. This is attributed to its rich history of technological advancements and robust engineering capabilities, positioning Japan as the home to foremost medtech companies. Japanese medical device innovation demonstrates a notable strength in addressing healthcare needs for the elderly, particularly through the implementation of robotics solutions. This emphasis is driven by a discerned recognition of unmet needs within this demographic (Jakovljevic et al., 2021).

Diverse applications within digital health include big data and analytics for enhanced healthcare management, drone utilization for delivery, AI in medical records, data governance, cybersecurity, wearable technology, the IoT for patient management and data collection, mHealth interventions, blockchain for data protection, digital identity provision, and supply chain integrity, as well as robotics for enhancing healthcare delivery efficiency (Thomason, 2021a).

Anticipating future shifts, three significant changes are on the horizon: the entry of large tech companies into the healthcare industry, monetization of consumer data with the development of health data marketplaces, and Asia emerging as a leader in digital health (Thomason, 2021a). While historically the US and Europe have been at the forefront of health tech, the Asian digital health sector is expanding at twice the rate of the US and Europe combined. Asia is projected to experience the highest growth among regional markets, contributing 35% of the overall growth from 2021 to 2028 (Thomason, 2021b).

Asia stands out as a global epicenter of rapid population growth, compounding the challenge of an aging demographic. This demographic shift exerts significant pressure on the healthcare system, necessitating innovative strides toward digital transformation. Technology emerges as the beacon promising to empower Asia in addressing it's escalating healthcare demands, uplifting the quality of life and surmounting barriers to access. Key facets of this digital metamorphosis include the integration of telehealth and the application of remote patient analytics. Forecasts paint a compelling picture, foreseeing an impressive journey ahead for the Asia-Pacific digital health industry.

Anticipating a compound annual growth rate of 34.2% over the next 5 years, as underscored by the HealthXL Research Team in (2020), this expected surge underscores the region's unwavering commitment to leveraging technology as a central force in transforming healthcare delivery and management. The COVID-19 pandemic hastened the digitization of healthcare, which will lead to a significant change in the delivery of patient-centered care. The big tech giants are already making inroads into the healthcare industry. Asia, which has the largest population in the world, will lead the way in digital health and be the largest provider of data (Thomason, 2021a). The penetration of smartphones is rising quickly, and wearable technology is becoming more and more popular.

The pandemic lowered obstacles, such as patient acceptability, and hastened the movement to handle patients who do not require critical care outside of hospitals. Asian health technology businesses stepped up to offer fresh approaches to the pandemic's battle (Thomason, 2021a). A telemedicine system based on the well-known social media WeChat was created in China to monitor patients who need home quarantine using a methodology akin to this (Xu et al., 2020). The popular Telegram app among Malaysians was used in this study to send the CoSMoS symptom tracking bot. Governmental departments and agencies use Telegram to spread health awareness and COVID-19 news.

Patients would discover the current digital platform more user-friendly due to their existing familiarity with the app. An analogous COVID-19 symptom-monitoring program tailored for Korean military healthcare facilities incorporated an additional model prediction programming interface to assess whether a patient required medical attention (Heo et al., 2020). The digitalization landscape in Asia is undergoing a revolution, predominantly propelled by China, outpacing Western markets. China, as part of its Healthy China 2030 initiative, is digitizing healthcare through apps, wearables, and virtual doctor programs, aiming to enhance efficiency, alleviate hospital pressures, and foster connections among patients, physicians, and the broader population.

Every participant in China's healthcare ecosystem—doctors, patients, and consumers—contributes to the services and information crafted by Asian digital healthcare entrepreneurs. China is at the forefront of the mobile payments revolution, encompassing public health insurance coverage for telemedicine, government-led digitization of pricing and information, and digital giants creating billion-dollar businesses using AI and advanced analytics for managing public health data or facilitating online physician consultations (Thomason, 2021a). China is intensifying research and development spending, particularly in integrating AI into clinical and e-health care. A notable breakthrough is the globally unprecedented 5G-network-mediated robotic neurosurgery conducted at the Chinese P.L.A. General Hospital in Beijing by a surgeon, Ling Zhipei, who was in Sanya City, Hainan, performing the operation in real-time (Wong, 2023).

Looking ahead, the medical technology industry in Asia is projected to generate US$142.10 billion by 2023, with medical devices, the largest market category, expected to reach US$112.80 billion in the same year (Statista, 2023). The medical device market in Singapore is anticipated to undergo a compound annual growth rate (CAGR) of 7.4% from 2022 to 2027, primarily propelled by the demands arising from the senior population and advancements in healthcare supply, as reported by HealthCareAsia in 2023.

The evolution and growth of the healthcare travel industry in Asia

Numerous Asian countries, including Singapore, Thailand, Malaysia, India, and South Korea market themselves as the best places for healthcare travel (Wong et al., 2014). Several factors contribute to the popularity of these regions, including outstanding clinical care, a dedicated commitment to quality, the utilization of cutting-edge medical technology, cost-effectiveness, international accreditation, politically stable governance, top-notch healthcare infrastructure, and exceptional tourism offerings (Turner, 2007; Wong & Sa'aid Hazley, 2020; Wong et al., 2014). Healthcare travel businesses that speak for healthcare delivery systems in the host nations frequently put together these packages expertly (Gupte & Panjamapirom, 2014; Ratnasari et al., 2022).

The surge in globalization within healthcare services has resulted in a notable uptick in healthcare travel (Heung et al., 2011). This expansion is chiefly driven by the private sector, with active participation from governments in Southeast Asia, East Asia, and South Asia contributing to the industry's growth. Hospitals, along with service providers like specialized travel agencies, play a pivotal role, in employing diverse marketing strategies to promote healthcare tourism.

In recent developments, Singapore witnessed collaboration between the government and the business community to establish a medical hub. Simultaneously, India emerged as the fastest-growing market in healthcare travel, attributed to its cost-effective medical care and substantial private-sector investments (Jadhav et al., 2014). This growth has led to a reduction in national regulatory barriers, simplifying the process for patients seeking medical treatment abroad (Wong & Musa, 2012).

The accreditation of some Indian hospitals by the Joint Commission International (JCI) has bolstered the credibility of the Indian medical system, fostering trustful relationships between foreign patients and Indian healthcare institutions and specialists. Currently, the clinical and paramedical expertise in India enjoys international acclaim, with numerous physicians in healthcare travel destinations holding board certifications obtained through cross-border medical training. Many of these professionals have received their professional education in industrialized nations and have often practiced in the countries where they underwent their training (Jadhav et al., 2014).

A $318 million project to build medical facilities has emerged due to Taiwan's promotion of international medical travel. South Korea is building medical facilities for its foreign patients, trailing closely behind in the fight for healthcare travel (Sharma, 2013). According to one set of estimates by Horowitz et al. (2007), a heart bypass surgery is $210,000 in the United States and $12,000 in India. It could be difficult to resist such cost reductions of 10-fold, which would increase the number of foreign patients in South Asian nations. This, combined with easier access to affordable international travel from nations like India, encourages people from other countries to seek medical care and services (Jadhav et al., 2014).

During the apex of the Asian Financial Crisis in 1998, the Malaysian government initiated the promotion of healthcare travel as a strategic move to diversify the travel and health sectors (Moghavvemi et al., 2017). Following this, both public and private sectors have actively sought to allure medical tourists willing to pay premium rates, particularly in Indonesia. Indonesia, renowned for its sustainable attributes, significant patient volumes, and cost-effectiveness, has been a focal point in these efforts (Ormond et al., 2014).

Over the past decade, Malaysia has systematically built a robust reputation as a dependable and secure international healthcare destination, attracting patients globally for diverse therapies (The Star, 2023). In the forthcoming phase, the industry aims to harness its full potential by encompassing preventive treatments and healthcare, with a special emphasis on services such as in vitro fertilization (IVF), cardiology, oncology, orthopedics, neurology, dental care, esthetics, and general health screening. Presently, Malaysia stands alongside India, Thailand, Singapore, and South Korea as among the premier destinations in Asia for healthcare travel (The Star, 2023).

Indonesian hospitals are poised to provide healthcare travel services while adhering to international standards. Notably, Bali Royal Hospital (BROS) ventured into the healthcare travel sector in 2010, establishing a modern-design private hospital in Denpasar. Recognized as a regional referral center by patients from Eastern Indonesia, it holds accreditation from the International Standards Organization (Ratnasari et al., 2022; Sandberg, 2017).

As a leading center for healthcare travel, Thailand is home to cutting-edge medical facilities, an increasing influx of foreign patients, HCPs, high-quality healthcare at competitive costs, and a substantial medical device market accessible to both domestic and foreign patients (Jakovljevic et al., 2021). In addition, Thailand also boasts a well-established pharmaceutical industry, both publicly and privately (Thavorn et al., 2021), supporting the healthcare travel industry strategically.

The report shows that Asian medical travel has been increasingly well-liked, with an annual growth rate of 15%, and a global market share of over 35% (Qualtech, 2023). The rising cost of surgery is posing a financial challenge to governments that provide universal healthcare. These are the reasons why patients are looking for international medical care. Asian healthcare providers give top-notch facilities, highly qualified physicians and medical staff, and various reasonably priced treatments and procedures.

Various patterns of patient flow related to international healthcare travel in Asia exist, with the majority being within the same region (Chee et al., 2017). These flows often arise due to the lack of adequate treatment facilities or accessibility in patients' home countries. Governments across Asia actively promote and facilitate healthcare travel by enacting laws, easing restrictions, and offering financial incentives to private hospitals to expand their patient outreach beyond borders.

A new era in the progression of medicine is emerging, facilitated by recent technological advancements, enabling the development of more specialized treatments. Precision medicine, exemplified by the provision of complementary equipment or digital diagnostic tools, plays a pivotal role in this evolution (Yeganeh, 2019). According to Ratnasari et al. (2022), medical vacation packages include a range of services, such as treatments at set costs, airfare, transportation, food, healing therapy, and extra excursions to well-known locations to draw patients from industrialized nations.

COVID-19 pandemic and its influence on the healthcare travel industry

The onset of the COVID-19 pandemic marked a seismic shift for the healthcare travel industry, once buoyed by the globalization of medical services (Kim & Hyun, 2022). As nations grappled with a complex web of disruptions, ranging from the immediate public health crisis to travel restrictions and the prioritization of domestic healthcare strained the industry. The profound impact was evident in destinations reliant on healthcare travel, such as Thailand, Malaysia, and India, where hospitals experienced financial downturns due to the abrupt cessation of international patient influx (Supasettaysa, 2023; Tatum, 2022; Yadav, 2022), underlining the need for diversification in revenue streams to enhance resilience in the face of unforeseen crises.

Before delving into the impacts, it's essential to acknowledge the preexisting vulnerabilities in the healthcare travel industry. The sector was already susceptible to external shocks due to its dependence on cross-border movement, stringent regulations, and the inherent variability in global healthcare standards (Connell, 2013). The pandemic has accentuated these vulnerabilities certainly. Stringent travel restrictions, border closures, and lockdowns aimed at curbing the virus's spread have severely limited international patient mobility. This abrupt halt to the influx of medical tourists has had profound economic ramifications for countries heavily reliant on healthcare travel as a revenue stream.

Beyond economic repercussions, the pandemic reshaped patient priorities and perceptions of healthcare travel. Fear of virus exposure during travel and concerns about the adequacy of healthcare in destination countries led to a shift in patient mindset. The pandemic has underscored the importance of robust healthcare infrastructure, leading patients to prioritize proximity over perceived cost savings in their decision-making process. A growing preference for domestic healthcare services has been observed, even for procedures traditionally associated with healthcare travel (Stackpole et al., 2021).

The healthcare travel industry's response to these challenges has been characterized by a pivot toward digitalization and telemedicine. The pandemic has accelerated the adoption of virtual consultations, pretravel medical assessments, and postoperative follow-ups. This shift aligns with the broader global trend toward digital health, as highlighted by the World Health Organization (WHO, 2023). Telemedicine not only addresses the immediate challenges posed by travel restrictions but also opens avenues for enhancing the overall patient experience and improving healthcare accessibility in the long run.

Despite the industry's adaptive measures, the trajectory of the healthcare travel sector remains puzzling. Persistent concerns surrounding the emergence of new viral variants and the looming possibility of extended travel restrictions add layers of uncertainty to the industry's recovery. The need for a synchronized global response to the pandemic is unmistakable, underscoring the WHO's call for international collaboration. The WHO's advocacy aims to ensure an equitable distribution of vaccines on a global scale, emphasizing the interconnectedness of health systems and the imperative to mitigate the pandemic's impact worldwide (WHO, 2023).

This uncertain landscape necessitates a nuanced and comprehensive approach from industry stakeholders. The anticipation of potential hurdles, such as the protracted presence of travel restrictions and evolving viral strains, demands strategic planning and resilience. Moreover, the ethical dimension of healthcare travel becomes more pronounced, as the industry grapples with the responsibility to balance economic interests with global health equity considerations (Ormond et al., 2014). In the face of ongoing uncertainties, the healthcare travel industry must remain vigilant and adaptive. Collaborative efforts at both national and international levels are pivotal for navigating the intricate challenges posed by the pandemic.

Besides, the global health crisis instigated a profound reassessment of the ethical dimensions within the healthcare travel industry. The pandemic has starkly illuminated the existing disparities in healthcare access, not only within individual nations but also across different countries. As nations confront the challenges within their domestic healthcare systems, a heightened consciousness has emerged regarding the ethical ramifications associated with prioritizing healthcare travel over addressing local healthcare needs. This ethical quandary underscores the necessity for a nuanced and comprehensive approach to healthcare travel, one that considers the broader implications for global health equity.

This ethical introspection aligns with a broader discourse on the ethical considerations of healthcare travel. The industry's impact on local communities, potential exploitation of healthcare resources, and the exacerbation of existing health inequalities have been subjects of scholarly scrutiny (Ormond et al., 2014). The current global health crisis serves as a catalyst for intensifying these discussions, emphasizing the need for ethical frameworks that balance the economic interests of the healthcare travel industry with the imperative of addressing systemic health disparities.

Impact of digital healthcare on the relevant stakeholders during the pandemic

Monaco et al. (2021) report that fewer in-person medical evaluations for individuals with noncommunicable diseases (NCDs) were conducted during the COVID-19 epidemic. As a result, healthcare providers had to quickly adapt new methods for monitoring and communicating with their patients. One of these tactics is the use of digital health tools. However, the possible advantages of employing digital health tools to manage NCDs may have needed to be improved due to patient preferences, privacy concerns, overregulation, and lack of legislation. According to van Kessel et al. (2023) following the pandemic announcement, search behavior for digital health shifted, and this behavior continued to emerge in the later stages of the pandemic. The number of searches on health apps either did not change or increased over time during the pandemic. There are many more uses for health apps (e.g., prevention, fitness, and managing subclinical health concerns). Furthermore, many health apps were developed and promoted for surveillance (i.e., creating vaccine passports and tracking immunization status) throughout the pandemic. The benefits of digital health are gradually becoming more apparent, and when traditional healthcare is interrupted, the general public also looks for digital health services (van Kessel et al., 2023).

Digital health tools might include devices like telemedicine that facilitate better contact between patients and HCPs, EHRs, symptom-monitoring smartphone apps, and appointment and prescription reminder systems (McKay et al., 2018; O'Connor et al., 2016). Digital health tools have been deployed in the COVID-19 pandemic for several purposes, including telemedicine services, digital communication, and remote patient monitoring. Therefore, scientific and political authorities use digital data monitoring to analyze the evolution, spread, and public perceptions of the virus (Fagherazzi et al., 2020; Golinelli et al., 2020).

Nevertheless, there is significant variation among nations, and most lack a legal framework for approving, integrating, and compensating for telemedicine services (Ohannessian et al., 2020). The utilization of digital health tools has rapidly changed due to the COVID-19 epidemic as highlighted by Monaco et al. (2021). Digital tools (such as telemedicine and video consultation technologies) to enhance communication between HCPs and patients increased throughout the pandemic.

While the pandemic has limited the extraordinarily large-scale tourism and healthcare travel economic streams to grow (e.g., Thailand, Malaysia, India), over 100,000 cases have been serviced by physician teleconsulting services at the beginning of 2020, partly because of the COVID-19 pandemic (Xu et al., 2020). Realizing the upward trend of technology requirements in healthcare travel, some are taking the pandemic as an opportunity to reposition itself, such as Thailand, where the National Board of Investors has developed a thorough plan to position the nation as the central Asian hub for biomedical technology (Pattharapinyophong, 2019).

Debatably, patients and medical providers speculated that the pandemic could potentially empower citizens to engage with digital technologies and contribute to research collecting data on digital healthcare and NCD prevention (Monaco et al., 2021). However, this raised concerns about privacy and ethical considerations among some patients who may also seek more information about digital alternatives to traditional in-person healthcare.

The perspectives of patients and healthcare providers may diverge based on the purpose of the digital health tool, with distinct needs arising for patients with varying conditions. Rather than a complete shift from nondigital to fully digital NCD management, the emphasis should be on leveraging digital health tools to enhance overall healthcare (Monaco et al., 2021). In the context of NCDs, in-person consultations are often not viable, especially during the COVID-19 pandemic when teleconsultations have proven beneficial by reducing face-to-face encounters and the risk of SARS-CoV-2 infection.

Effective communication between scientific authorities and political leaders is imperative during a pandemic (Westman, 2020). The prevalence of "fake news," misinformation, and conspiracy theories surrounding the COVID-19 epidemic has been rampant, leading to confusion and mistrust within the community (Fagherazzi et al., 2020).

Digital approaches, such as health notifications through platforms like WhatsApp, offer a practical means to keep individuals informed and connected while physically distant.

Digital health also significantly influences government policy, as seen in efforts to educate the public about proper conduct during lockdowns and other health-related topics. Practical strategies employed in prior pandemics include the use of apps for remote communication between ministries or health agencies and health workers, as well as providing notifications to government officials about symptoms, case numbers, and preventive measures (ICTworks, 2017; WHO, 2021). Excessive exposure to contradictory information and sensational headlines in mass and social media can negatively impact the population's mental health and contribute to heightened anxiety (Ni et al., 2020).

An app called TraceTogether is used in Singapore to monitor patients who have COVID-19 infection. Bluetooth is a tool that Singaporean health officials can use to track people and alert them if they come into contact with a COVID-19 patient (Payments News & Mobile Payments Trends PYMNTS, 2020). Much attention has been paid to South Korea's handling of the COVID-19 pandemic, often cited as an example for other Asian nations. South Korea's digital privacy rules have been relaxed since the 2015 MERS crisis, which has resulted in several all-encompassing digital solutions. These consist of a nationwide smartphone app, GPS tracking of people, and all-inclusive emergency notifications issued upon discovering a positive case.

Governments usually need help with establishing practical procedures when it comes to telehealth (Keesara et al., 2020) since invoicing systems need to be modified (Hollander & Carr, 2020). Data security for patients must also be guaranteed during telemedicine consultations. Therefore, it is necessary to guarantee strong cooperation between health technology businesses and healthcare providers (Hollander & Carr, 2020). Several developing nations confront significant challenges in providing digital health solutions in rural and remote areas. These challenges include inadequate or incomplete basic digital infrastructure (such as Internet networks, computers, and electricity), a lack of management, education on digital platforms use, and expensive telecommunications (Mahmood et al., 2020; Muinga et al., 2020).

In 2020, Pain Alliance Europe conducted an online study focusing on mobile health (mHealth)—the utilization of mobile devices for medical purposes—and eHealth, referring to information and communication technology in healthcare. The study gathered data from 1789 chronic pain sufferers across 28 European countries. Surprisingly, 46.28% of respondents reported not utilizing eHealth or mHealth services. A significant factor contributing to this trend, identified by 54.17% of participants, was their lack of awareness about eHealth and mHealth services. Additionally, 16.17% of respondents cited a perceived absence of personal benefits as a reason for not engaging with these services.

The Pain Alliance Europe (2020) survey also revealed that patients could utilize mHealth and eHealth services to self-manage their diseases, which was the most prevalent reason for doing so. 9.86% of patients who used eHealth or mHealth services, shared their health information with their primary care physician, whereas almost half (48.84%) did not share it with anyone. Concerns over data privacy and the recipients of personal information—such as banks, employers, and insurance companies—have been voiced by many people. Patients are unlikely to completely accept digital healthcare tools unless privacy issues are sufficiently resolved.

Case study—keeping the healthcare travel industry relevant in Penang, Malaysia, during COVID-19 pandemic: the adoption of digital healthcare

Malaysia is among the top healthcare travel destinations in Asia, where, along with Kuala Lumpur, Melaka, Johor Bahru, and Kuching, Penang is highly active in the healthcare travel industry. In 2019, Penang welcomed a staggering 480,000 medical tourists, encompassing nearly half of Malaysia's total healthcare travel demand (Dermawan, 2023). The region's allure lies in its provision of high-quality, affordable healthcare services, cutting-edge medical treatments, and a picturesque island leisure environment (Nazem & Mohamed, 2016). Penang not only significantly bolsters the state's economy but also contributes significantly to the nation at large (Wong et al., 2014). The active participation of the Penang state government and the Penang Centre of Medical Tourism (PMED) serves to amplify the growth and promotion of healthcare travel in the area.

The reported revenue from medical tourists in 2021 amounted to RM66 million (approximately US$15.5 million) (Dermawan, 2023). This figure experienced an exponential surge, reaching RM356 million (approximately US$75.6 million) in 2022, contributing about 27% (RM 356 million) to total Malaysia's 2022 revenue (Mulyanto, 2023). The majority of these medical tourists hailed from Indonesia, Bangladesh, and India (Dermawan, 2023). Popular medical treatments sought by these visitors include orthopedics, general surgery, cardiology, dental work, and cosmetic surgery (Malaysia Healthcare Travel Council, 2024; Nazem & Mohamed, 2016). Penang's reputation also extends to traditional and complementary medicine offerings, encompassing traditional Chinese medicine and Ayurveda.

While the 2022 revenue escalated following the reopening of international borders, it only constitutes of 49% of the revenue generated in 2019 (pre-COVID period). Hence, the vulnerability of the industry became apparent during the pandemic, raising concerns about its sustainability. The influx of medical tourists significantly dropped during pandemic, and the industry faced challenges such as increased competition, changing consumer preferences, and strain on the local healthcare system (Ormond et al., 2014).

To confront these challenges head-on, the adoption of Industry Revolution 4.0 (IR 4.0) technologies emerges as a strategic imperative. These advanced technologies, encompassing the IoT, AI, cloud solutions, advanced automation, robotics, and big data analytics, promise to revolutionize traditional practices in the healthcare industry

(Wong & Sa'aid Hazley, 2020). Their application extends beyond improving patient outcomes, cost reduction, and operational efficiency to addressing mobility constraints and enhancing the overall patient experience.

Crucially, these technologies are positioned to aid private healthcare facilities in Penang to remain relevant and provide remote support to their medical tourists. Thus, the adoption of these cutting-edge technologies becomes a pivotal strategy to reshape Penang's healthcare travel competitiveness, ensuring a more resilient and competitive landscape postpandemic.

According to Wong et al.'s (2021) investigation involving six of Penang's thirteen private healthcare facilities, the incorporation of digital healthcare has played a pivotal role in these institutions successfully addressing the hurdles posed by the pandemic. Remarkably, the adoption of technology has been an integral component of their overarching business growth strategy, and the extremity of the pandemic has acted as a catalyst, propelling this agenda forward. The study highlights several key digital healthcare strategies adopted during the pandemic among the Penang private healthcare facilities:

Telemedicine: The pandemic served as a catalyst for the rapid assimilation of telemedicine into the healthcare landscape, presenting healthcare travelers with a valuable avenue for remote interaction with professionals. This expedited integration not only adeptly addressed the formidable challenges imposed by travel restrictions but also showcased a compelling alternative that was both cost-effective and efficient. By embracing telemedicine, healthcare providers found themselves equipped to deliver essential medical services without the need for physical presence, underscoring the adaptability of the healthcare system in navigating unprecedented circumstances. This paradigm shift not only exemplified a responsive solution to immediate challenges but also laid the groundwork for a transformative evolution in the delivery of healthcare services.

Take, for instance, esteemed private healthcare institutions like Bagan Specialist Centre and Penang Adventist Hospital, which highlight the transformative impact of communication technology. This advancement empowers medical professionals to monitor patients' health remotely, including vital signs, ensuring prompt and effective care. Additionally, telemedicine serves as a valuable tool for follow-up consultations, diminishing the necessity for patients to make the journey to healthcare facilities for posttreatment appointments.

Wearables: The integration of wearable technology, comprising devices like smartwatches and fitness trackers, played a pivotal and multifaceted role in the healthcare landscape. Beyond being mere accessories, these devices assumed a critical role in actively monitoring and managing the health of patients. The real-time data collected facilitated not only the swift identification of potential health issues but also empowered healthcare travelers with continuous feedback, thereby enriching and personalizing their overall healthcare experience. This dynamic engagement went beyond traditional healthcare delivery methods, forging a more interactive and proactive approach to patient care. The seamless integration of wearable technology underscored its transformative potential in shaping a new era of patient-centric healthcare that prioritizes real-time monitoring and personalized interventions.

Illustratively, Penang Adventist Hospital and Bagan Specialist Centre elucidated the integration of wearables in patient care. These devices are affixed to patients, capturing vital signs and feeding the data into the Early Warning Score system (EWS), which diligently oversees their conditions. This proactive approach enables timely alerts to HCPs, elevating the speed and quality of medical care. Furthermore, wearables, ranging from fitness trackers to specialized medical devices, are extended to medical tourists for continuous health monitoring upon their return to their home country. This information is seamlessly transmitted to HCPs in Malaysia through channels such as email or dedicated mobile applications.

Electronic medical records (EMRs) and cloud solutions: The strategic deployment of EMRs and cloud solutions emerged as a cornerstone in the continuous evolution of medical care. These technological implementations went beyond mere administrative enhancements; they played a pivotal role in elevating the efficiency and precision of healthcare services. By digitizing patient records, EMRs facilitated seamless access, retrieval, and exchange of critical medical information, transcending geographical boundaries. This not only streamlined local healthcare operations but also laid the foundation for collaborative endeavors on an international scale. The interconnected nature of cloud solutions enabled HCPs to share insights, consult on cases, and collectively contribute to a global pool of medical knowledge. The implementation of EMRs and cloud solutions thus not only optimized individual patient care but also fostered a collaborative and interconnected global healthcare community.

Consider establishments such as Bagan Specialist Centre, Georgetown Specialist Hospital, and Island Hospital, which leverage EMRs to streamline and share patient information internally. This digitization enhances the efficiency and precision of medical care. EMRs play a pivotal role in granting doctors access to a comprehensive medical history, encompassing past test results and treatments, aiding in accurate diagnosis and treatment planning. Notably, Penang Adventist Hospital seamlessly integrates hospital information through a mobile application. Simultaneously, Genesis IVF & Women's Specialist Centre underscores the significance of data integration in facilitating customized analyses tailored to individual user requirements.

IoT and big data analytics: While the incorporation of IoT technology remained somewhat limited, healthcare facilities in Penang strategically harnessed the potential of data sourced from wearables and EMRs to monitor and analyze vital signs. Despite the restrained adoption of full-scale IoT, this targeted use of wearable data and electronic records allowed for the real-time tracking of patients' essential health metrics. Furthermore, the transformative impact of big data analytics became increasingly apparent within Penang's healthcare travel sector. By processing and interpreting vast datasets, big data analytics not only provided valuable insights into patient trends but also became a catalyst for innovation, steering the industry toward enhanced patient outcomes and operational efficiencies.

The private healthcare facilities in Penang that were studied by Wong et al. (2021) have not fully embraced IoT initiatives. Although certain establishments may extract data from their social media platforms for consumer behavior analysis, none of them has reported delving into the wealth of consumer data potentially accessible through their Wi-Fi connections, online chat interactions, or e-wallet transactions within their premises.

Cutting-edge technologies and robotics: Penang's commitment to advancing healthcare is evident in its adoption of state-of-the-art medical equipment and integration of robotic surgery, showcasing a proactive embrace of technological innovations. This dedication to delivering cutting-edge treatments extends beyond attracting healthcare travelers, playing a pivotal role in enhancing the precision and success rates of diverse medical procedures. The strategic investment in cutting-edge technology positions Penang as a frontrunner globally, emphasizing its commitment to providing patients with access to the latest medical interventions. Beyond its appeal to healthcare travelers, this technological prowess cements Penang as a hub for innovative and successful medical treatments, solidifying its influential position in the global healthcare arena and reinforcing its commitment to excellence and patient-centric care.

Penang Adventist Hospital stands out for its capability to administer Proton Beam therapy for cancer treatment, while Genesis IVF & Women's Specialist Centre boasts a time-lapse incubator tailored for advanced fertility treatments. In the realm of healthcare travel in Penang, the integration of Industry 4.0 technology is evident in robotic surgery. Bagan Specialist Centre, for instance, harnesses robotics to enhance precision in orthopedic surgery, showcasing the progressive adoption of cutting-edge technologies in the industry.

Wong et al. (2021) also delves into the intricate web of factors propelling the implementation of digital healthcare strategies within Penang's private healthcare facilities amid the pandemic. The driving forces below encapsulate a multifaceted spectrum, ranging from the imperative need for streamlined operational efficiency to the compelling value creation for both the healthcare facilities, HCPs, and healthcare travelers

Efficient operation: These transformative technologies are able to elevate operational efficiency within the healthcare facilities, leading to a substantial reduction in waiting times for patients. The streamlined processes not only expedited the delivery of healthcare services but also contributed to an overall enhancement in the mobility and connectivity of the healthcare ecosystem. Patients experienced a more seamless and timely access to medical care, reflecting the tangible benefits of these advanced technologies on the operational dynamics of the healthcare facilities.

Return on investment (ROI): Private healthcare facilities underscored the critical significance of ROI as a cornerstone in their strategic decision-making processes. Their commitment to achieving a substantial ROI was not merely a financial consideration but a strategic imperative, as these institutions sought to forge a competitive advantage through the judicious adoption of technology. The overarching objective was not only to ensure the financial viability of their operations but also to cultivate a sustainable business model that could withstand the dynamic challenges of the healthcare industry. The emphasis on ROI reflected a nuanced understanding of the delicate balance between financial prudence and the imperative to remain at the forefront of technological innovation for long-term success and resilience.

Customer satisfaction: In the face of certain constraints experienced by the healthcare travelers, the proactive and adaptive measures undertaken by healthcare facilities in navigating the prevailing circumstances played a pivotal role in fostering heightened levels of customer satisfaction. Rather than viewing limitations as insurmountable hurdles, these facilities demonstrated a remarkable responsiveness to the challenges, implementing digital healthcare strategies and initiatives that directly addressed the specific concerns faced by healthcare travelers. This responsiveness went beyond mere problem-solving; it encompassed a comprehensive approach that considered the unique needs and expectations of patients, thereby contributing significantly to an elevated sense of satisfaction among the clientele. The recognition and effective management of these limitations not only underscored the facilities' commitment to patient-centric care but also reflected their agility and dedication to ensuring a positive and gratifying healthcare experience.

Value creation: Technology adoption served as a transformative force in enhancing the value creation process within healthcare facilities. It revolutionized traditional patient care models, empowering doctors to engage with a broader healthcare traveler base, optimizing practitioner efficiency, and facilitating timely interventions. Additionally, technology integration emerged as a pivotal element in elevating overall medical procedure success rates. Leveraging advanced diagnostics, data analytics, and real-time monitoring, healthcare providers could tailor interventions to individual needs, fine-tune treatment plans, and mitigate potential complications. This strategic embrace of technology positioned medical practitioners at the forefront of advancements, fostering a culture of continuous improvement in patient outcomes. Beyond operational efficiency, the holistic impact extended to qualitative transformations in the patient experience, showcasing technology as a vital enabler for healthcare providers to navigate the complexities of modern healthcare with agility, innovation, and an unwavering commitment to patient well-being.

The case study highlights the pivotal role of digital healthcare in reshaping Penang's healthcare travel industry, ensuring its relevance during the pandemic, and enhances its competitiveness and sustainability postpandemic. The strategic adoption of healthcare technologies not only addressed immediate challenges but positioned Penang as a technologically advanced and resilient destination for healthcare travelers. Nonetheless, a consensus among these facilities is that technological progress is viewed more as a supplement than a substitute. This perspective is rooted in persistent concerns about security, prompting a careful deliberation of the costs and benefits associated with investing in technological advancements.

Conclusion

In the face of the intricate hurdles posed by the recent pandemic in the healthcare travel industry, a digital rhythm has adeptly synchronized, fundamentally altering our comprehension and engagement with medical services. Venturing through the realms of digital healthcare, a notable transformation unfolded, steering away from the traditional model toward an innovative digital ecosystem. The landscape of healthcare in Asia emerged as a ground for digital transformation, with growth and trends sprouting in every direction. The healthcare travel industry, once confined to physical borders, began to spread its wings digitally, breaking barriers and redefining geographical constraints.

Yet, the storyline pivoted unexpectedly with the intrusion of an unwelcome guest—the COVID-19 pandemic. Remarkably, this global crisis, while disrupting established norms, served as a potent catalyst for transformation. The imperative of digital healthcare during the pandemic became unmistakably clear, emerging as a vital support for individuals contending with both physical and mental health challenges. The advent of the virtual domain served as an innovative frontier for medical consultations, offering crucial support during periods of disorder. As the multifaceted orchestration of digital healthcare continued, its impacts resonated across a diverse array of stakeholders.

Healthcare institutions grappled with recalibrating their strategies, doctors adeptly navigated the nuances of telemedicine, and patients embraced the convenience of virtual healthcare. This paradigm shift prompted policymakers to reassess regulations and frameworks, adapting to the evolving landscape. The progression and growth of digital healthcare in Asia, coupled with the transformative journey of the healthcare travel industry, have woven a narrative of resilience and adaptability. The COVID-19 pandemic, though disruptive, ushered in an era where the importance of digital healthcare cannot be overstated. The impact of digital healthcare on stakeholders stands as a testament to the sector's ability to not just weather storms but to emerge stronger and more connected than ever before.

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CHAPTER 14

AI-powered digital health: bridging the gap for elderly populations in the evolving healthcare ecosystem

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Introduction

The global population is experiencing a significant shift towards ageing, and this phenomenon is particularly pronounced in the Asia-Pacific region, which is dignified to witness the rapid increase in its elderly population between now and 2050 (Weforum, 2021). Statistics indicate that the number of older individuals in Asia and the Pacific is set to more than double, soaring from 630 million in 2020 to approximately 1.3 billion by 2050 (Census, 2022a). Within this context, Asia faced an estimated 414 million citizens aged 65 and older in 2020, with expectations that this figure will swell to over 1.2 billion by 2060 (ESCAP, 2023). The Association of Southeast Asian Nations (ASEAN) is not exempt from this demographic shift, as highlighted by the 2020 Older Persons in ASEAN in numbers datasheet, which provides valuable data on key indicators reflecting the ageing population and the circumstances of older individuals in ASEAN member states (ESCAP, 2021a). According to 2019 data, ASEAN countries were home to 46.8 million people aged 65 or above. Moreover, it is predicted that by 2030, the majority of ASEAN member countries, including Singapore, Thailand, & Vietnam will transition into ageing societies, while Singapore and Thailand will enter the category of aged societies (ASEAN, 2021; Jia et al., 2023). These compelling statistics underscore the urgent need for research, policies and systems geared towards enhancing the well-being of older individuals through strategic investments made throughout their lifecycles (KPMJ, 2021).

Digitalization has impacted every aspect of human life, including the elderly population. As technology advances, humans can now easily pay, communicate, learn, and engage in leisure activities. The advancement of digital technologies has not only improved our everyday lives but also has the potential to transform the healthcare sector by enabling the adoption of digital health technologies. The success of digital health

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should encompass all layers of society, including the elderly, whose population continues to grow. There are many benefits for the elderly in having access to digital health, such as telehealth facilities. However, the speed of information technology poses a challenge for the elder group to get full benefits from digital health technology.

Post-Coronavirus 2019 (COVID-19), many healthcare centers have been implementing the use of digital healthcare where medical professionals can easily engage with their patients without having to physically interact with them (Anshari et al., 2023c). The role of digital health can also be applied to governments to collect data from the public and then use it for the purpose of monitoring the spread of any potential diseases, allowing the government to make preparations to reduce the risk of infection in the community. Importantly, when it comes to the use of digital health in the health sector, citizens and the government must develop trust and cooperation in order to ensure a productive workforce and efforts to resolve any challenges. Getting a faster response if there are inquiries or getting to book appointments by themselves through digital applications is one of the examples of a productive effort.

Therefore, knowledge management plays a critical role in the world of digitalization where every process and strategy is based on the information gathered 24/7 and useful for the government's decision-making (Anshari et al., 2023b). Aside from that, when information is accessible through these digital technologies, services provided can be enhanced and enable patient experience for the better. Finally, when services are quick, efficient, and simple to use, trust can be improved. The purpose of this research is to examine how the advancement of AI in digital health can also benefit the elderly within the continuously evolving healthcare ecosystem in the context of Asia (Anshari et al., 2023a).

Digital health

The increasing importance of digital technology in post-COVID-19 pandemic, enabling remote connections and convenient access to information. As the number of COVID-19 cases rises, governments have grown increasingly concerned and have had to rely on digital health to expedite the digitization of the healthcare industry. The concept of digital health, or digital healthcare, is broad, encompassing various technology and healthcare fields. Transforming the healthcare sector into a digitalized one involves the integration of software, hardware, and services.

Kostkova (2015) defines digital health as a tool that utilizes information and communication to enhance human health, healthcare services, and wellness for individuals and populations at large. Additionally, digital health can improve the healthcare system by providing direct services to people at their homes and monitoring outbreaks using digital tools such as e-health, m-health, telehealth, health data, and other efficient and responsive technologies (WHO, 2020a).

Moreover, the adoption of digital health technologies enhances the effectiveness of the healthcare system by leveraging mobile health applications and other disruptive technologies, promising higher-quality services and responsive healthcare (Anshari et al., 2021). As asserted by Peek et al. (2020), during pandemics, making data available for outbreak surveillance becomes a priority, ensuring that information supports operational needs, including hospital capacity planning and resource management. Furthermore, Daniel Castro stated that broader data sharing and utilization will bring significant benefits to the healthcare sector, encouraging more personalized and coordinated care, improving hospital quality, and expediting treatment development.

Despite its transformative potential in healthcare, the use of digital health also raises concerns about data protection and the costs associated with developing such technologies (Almunawar & Anshari, 2014). This entails safeguarding individual privacy and confidentiality, determining who will control both the technology and the data, identifying the funding sources, and addressing the inevitable resistance to change associated with digitalization (Mitchell & Kan, 2019). Controlling data breaches in the era of digitalization and modern technologies may prove challenging. However, as the world embraces digital innovation, human life becomes more convenient, and societies must adapt to these changes.

Regarding the costs of healthcare technologies, there is increasing pressure on governments to provide higher-quality healthcare, especially in middle-income countries, although low-income countries may face limitations due to budget constraints (Mitchell & Kan, 2019). Nevertheless, in many countries, health technologies can be developed through a hybrid model of funding sources, involving individuals, the private sector, external financial support, and government contributions. Consequently, health technology is likely to expand through these diverse payment models (Mitchell & Kan, 2019).

During the COVID-19 pandemic governments around the world have taken serious actions and have started implementing preventive measures to reduce and eliminate cases. In doing so, the government came up with several establishments on health systems that promised effective and efficient delivery of healthcare services during a pandemic.

One way that digital technologies are being used in the health sector is through the development of mobile applications such as contact-tracing apps during the COVID-19 pandemic. Governments around the world have encouraged citizens to install the apps on their smartphones, making it easier to monitor and track who each user has been in contact with. This does not only help governments to observe the public but it enables them to inform and warn those who are affected if in any case they are found to be positive for infection. Moreover, to have effective use of contact tracing apps, according to a research analysis, there is a need for 50% to 70% of the population users of the app so the people and government authorities would easily be informed of the affected areas or individuals (Akinbi et al., 2021). Furthermore, according to research conducted by Altmann et al. (2020), Italy is one of those countries that shows a greater need in population for installing contact tracing apps.

For example, as the country had started the second phase of the pandemic, the Italian Ministry of Health launched an app called "Immuni," a Bluetooth-based contact tracing tool, to confront and prepare for possible future waves after being terribly hit by the surge in cases and deaths during the first wave. The app continuously collects data information such as the town of residence and exchanges randomly generated codes (via Bluetooth function) with another "Immuni" user from a meter or less from each other. Thus, enabling the government to keep track of individuals who possibly have come into contact with positive cases.

The contribution of digital health technologies can also be seen in terms of data visualization. A data dashboard in times of pandemic is created for the purpose of planning, analyzing, tracking, and displaying real-time data and trends based on the information given from countries across the globe. Ever since the COVID-19 situation, the World Health Organization (WHO) has established the "WHO COVID-19 Dashboard" on their official website allowing access to the current update of COVID-19 cases and deaths around the world. Moreover, Oliver Morgan, a director of the Health Emergency Information and Risk Assessment Department, WHO Health Emergencies Programme, had also stated and urged that all countries should contribute to reporting their daily situation regarding the COVID-19 cases in the country so that more comprehensive insight about the epidemiology and responsiveness towards the COVID-19 situation can be taken at the global level (WHO, 2020b; 2020c).

For example, BruHealth, an app developed by the Ministry of Health in Brunei Darussalam, in an attempt to engage with the Bruneian people regarding the COVID-19 pandemic. The use of BruHealth is not only limited to tracing contacts and updates on personal health information, but it also provides general information based on visual graph statistics, maps, trends, nearby cases and other latest news so that the public can take precautionary steps in facing the pandemic. This app does benefit the government as well in tackling the rise of positive cases in the country by implementing national planning and other governmental decisions based on data statistics and other visual news updates in the app.

The establishment of digital health technologies also allows the public to make online bookings for an appointment, be it a vaccination appointment or a swabbing test (Almunawar et al., 2015). Allowing patients or the public in general to manage their own appointments empowers them to decide on scheduling at their own convenience and according to their time. This does not only be beneficial for every individual but also helps the government to control the public from overcrowding certain places such as the hospital, clinics or swabbing centers, which can be too dangerous to visit due to the higher risk of infection (Almunawar et al., 2012).

Telehealth can be defined as the use of electronic devices such as smartphones, tablets, computers, video technology and other devices to communicate remotely with health professionals regarding the patient's health conditions. To prevent any physical interaction between an individual (or patients) and doctors (or any other health professionals such as nurses, therapists, etc.), a video chat technology is developed for the purpose of medical appointments and consultations. Doctors may use this tool to conduct virtual consultations and ensure those positive patients or any individuals in general, receive the medical care or consultation they require. As these features are available, governmental levels will benefit when it comes to providing strategies such as in terms of executing safety measures, policies, guidelines and solutions to make better provision of public healthcare and services while aiming to flatten the curve.

While knowledge management is becoming a well-established field with structured applications and organized techniques, the importance of implementing knowledge management in healthcare has been emphasized. The healthcare sector highly values information and evidence, documented in medical records and used in daily healthcare activities, making it crucial for decision-making (Anshari & Almunawar, 2019). Healthcare providers, including personal physicians, specialists, nurses, radiologic technology technicians, lab technicians, social workers, psychologists, counselors, and others, collaborate with third parties such as hospital and clinic administrators, finance and human resources managers, health ministries, pharmaceutical companies, health insurance providers, activist groups, educational institutions, and research communities to provide better healthcare to the population. Therefore, it is evident that the volume of information received is substantial and must be handled with utmost care (El Morr & Subercaze, 2010). Furthermore, collaboration among healthcare partners results in the creation of knowledge transfer networks (Ansell, 2007; Wickramasinghe and Davison, 2004). Through various knowledge-sharing mechanisms and organizational factors, cooperation and innovation become attainable goals (Currie and Suhomlinova, 2006; Donaldson et al., 2005; Elliott and O'Dell, 1999).

Challenges for digital health

Without a doubt, the COVID-19 pandemic has brought the healthcare system on an unexpected journey of digital transformation. In fact, this has certainly accelerated the use of digital health in the healthcare sector. Despite the potential benefits to the health sector, the adoption of digitalization has raised several concerns among the general public and at the governmental level.

One of the greatest barriers to digital health adoption is security concerns. In order to combat this outbreak, the government has been collecting individual personal information on a continuous basis. This has resulted in massive amounts of data being collected, and there will be issues about who manages this data and how the general public can be assured that their data is safe and kept private. This has placed the government in a difficult position, as some parts of the population oppose the use of digital health, such as contract tracing, which involves the collecting of data on health issues, GPS location, and personal information. Furthermore, because contact tracing apps benefit the community on a broad scale, this data may be processed through credit card records, facial recognition through cameras, and cellular signals, inviting the risk of data exposure (Majeed, 2021).

The invention of such technologies may be costly. As a result of COVID-19, the government faced the rapid and mass spread of the novel coronavirus, creating the necessity and the urgent need to spend and invest in technologies in the healthcare sector. This includes the creation of telemedicine, improvement of hospital facilities (AI-based), electronic health records and other developments in health applications such as contact tracing apps that help in mitigating the risk of infection. This is not only applicable to the governmental level, but, the population itself, especially in low and middle countries. Digital technology and network infrastructure are particularly limited in low- and middle-income countries (Pinto et al., 2021). The listed countries may face challenges since smartphones or digital health technologies such as telehealth, require access to an internet connection and it can be considered costly to use by some part of the population.

Another challenge that may be overlooked is resistance to change. As the world is struck by the COVID-19 epidemic, individuals across the globe have been forced to adapt to a new way of life. The rapid deployment of technological innovation is used in several countries to fight the pandemic where certain people find it difficult to enter the digital world. Some of the population, especially the older generation and the healthcare providers, may not yet be adjusted to living in a digitalization where healthcare systems such as teleconsultation, telemedicine and wearables as well as the response to combat the outbreak through contact tracing apps are best suited in this current situation. People with this type of mind would instead prefer the traditional face-to-face consultation. Furthermore, this type of situation may occur due to feelings of insecurity among health professionals who aren't technically minded, or among people in general who aren't comfortable with digital developments. It was found out by European research that there were 28.9% of Europeans who lack basic digital skills and they are at risk to exclude the use of digital technologies in healthcare services.

Aritificial intelligence in digital health

Artificial intelligence (AI) is a computational system capable of processing and performing tasks that typically require human intelligence. In the healthcare sector, data is crucial and serves various purposes, including disease identification, chronic disorder management, healthcare service provision, and research and medication development. During COVID-19 pandemic has played the pivotal role of AI across critical phases, shaping our response to this global health crisis. First, Forecasting and Prevention, AI techniques are instrumental in detecting the presence of novel viruses, collecting vast datasets to predict their potential threat, outbreak potential, and transmission patterns. Notably, "BlueDot," a Canadian health-monitoring company, issued early alerts about the potential COVID-19 outbreak, outpacing official announcements by organizations like the US Centers for Disease Control and Prevention (CDC) and the WHO. AI's predictive capabilities are vital for healthcare preparedness and prevention.

The Emergency Operation and Response phase sees AI developing smartphone applications that facilitate effective government-public communication. These apps disseminate information on data statistics, policies, restrictions, and regulations, demanding immediate responses to mitigate the virus's spread. BruHealth in Brunei Darussalam exemplifies this, functioning as an epidemic response and population engagement platform that utilizes big data and AI to monitor public health, predict infection rates, map medical resources, and aid in government planning for enhanced healthcare infrastructure and policies.

AI's significance extends to the Prevention of Infection Spread and Treatment Research. It helps limit virus spread through measures like restricting population movement, temperature checks, and disease tracking. In China, individuals scan QR codes before entering specific areas, with different codes reflecting their health status. AI also accelerates drug development, treatment strategies, vaccine creation, and repurposing of existing medications, streamlining the approval process. 'BenevolentAI,' for example, analyzed and recommended the use of the rheumatoid arthritis drug Baricitinib to alleviate COVID-19 symptoms, leading to its successful development. AI's multifaceted contributions continue to advance our response to global health challenges.

Aging Asia and digital health

The aging population in Asia represents a significant demographic trend. The number of elderly individuals in Asia and the Pacific is projected to more than double, increasing from 630 million in 2020 to approximately 1.3 billion by 2050 (ESCAP, 2021b). In 2020, 13.6% of the population in Asia and the Pacific was aged 60 years or older, and by 2050, this proportion is expected to rise to one-quarter of the population. Asia's population is aging at a faster rate than any other region in the world. Within Asia, which includes countries with substantial aging populations such as Japan and the Republic of Korea, over a third of the population is expected to be 60 years or older by 2050 (UNESCAP, 2017).

The global population is undergoing an aging process, with the Asia-Pacific region likely to experience the most rapid increase in older citizens between now and 2050 (UNESCAP, 2017). As of 2020, Asia's population exceeded 4.5 billion, encompassing China and India, both of which have populations exceeding 1 billion each, collectively constituting more than half of the world's total population (CNN, 2023). There were an estimated 414 million Asians aged 65 and older, a figure approximately 20% higher than the entire U.S. population, which stood at 331.4 million (Census, 2022b). This demographic shift carries significant implications for social and economic policies in the region. It is imperative for countries to prepare for this change and ensure that older individuals can age with dignity.

Elderly individuals often face several challenges when it comes to using digital tools, including physical limitations. Approximately two out of five older adults have physical conditions and health issues that exacerbate the difficulties of using technology, including common health conditions like vision impairment, joint diseases, hearing impairment, and cognitive issues, all of which can hinder the effective use of digital devices or services. Moreover, many older adults respond to technological change with skepticism and intimidation, as the pace of digital innovation is often not inclusive of their needs. Understanding how new technologies work can also be a significant hurdle for older adults. The vast amount of online information can be overwhelming and confusing, and many older adults require assistance in learning to use handheld devices and digital services. Additionally, there can be fear of the unknown, anxiety about internet safety, and negative feelings about social media. Addressing these challenges is crucial for ensuring digital inclusion for older adults, and continuous training can help them progressively improve their digital skills. Furthermore, it is essential to develop measures to mitigate emerging risks related to misinformation, cybercrimes, safety, and privacy issues in order to create a more inclusive digital future for all (Husain et al., 2023).

Digital health technologies offer a multifaceted approach to significantly enhance the well-being of the elderly (Ordoñez de Pablos, 2023). They address Social Determinants of Health by providing access to clinical consultations, medical services, community resources, and educational materials for managing chronic diseases (Catalyst, 2017). Additionally, through the use of remote sensors, such as connected scales, blood pressure cuffs, and glucose monitors, these technologies enable continuous monitoring of vital health parameters. Apps designed to promote medication adherence offer reminders for seniors to take their medications as prescribed, while voice command technologies assist with device operation and service access. Predictive analytics, telemedicine, AI integration, and digital markers aid in early disease detection and health issue identification. Moreover, these digital tools empower seniors to monitor their health status, connect with healthcare professionals, and potentially reduce healthcare costs. They can also cater to sensory impairments and cognitive health, combat loneliness, assist with mobility, and employ wearable devices for real-time health tracking, ultimately improving the overall quality of life for older individuals. Nonetheless, it is essential to address gaps and challenges that may hinder older persons from fully benefiting from this digital transformation.

Methodology

This study employs a qualitative research approach to investigate the role of AI-powered digital health solutions in bridging the healthcare gap for elderly populations within the evolving healthcare ecosystem. The qualitative method is particularly suited for this research as it allows for an in-depth exploration of existing literature to synthesize insights and construct a comprehensive understanding of the subject matter. The primary data source for this research is a systematic and extensive review of existing literature in the fields of healthcare, gerontology, digital health, and artificial intelligence. A systematic approach is used to identify relevant peer-reviewed articles, research reports, and scholarly contributions. Keywords and search terms related to AI in healthcare for the elderly are used to conduct searches across academic databases. Articles and studies included in the literature review are selected based on their relevance to the research objectives, including their focus on AI-powered healthcare solutions for the elderly and their implications on healthcare workflows. Pertinent information from selected literature is systematically extracted, including insights on the challenges faced by elderly populations in healthcare, the role of AI technology, and existing AI Assistant healthcare workflows. The data collected from the literature review is subjected to thematic analysis. This process involves identifying key themes, patterns, and trends within the literature. Themes related to the challenges faced by elderly populations, the capabilities and limitations of AI-powered solutions, and the development of AI Assistant healthcare workflows are identified and examined. As this study relies solely on the analysis of existing literature, ethical considerations related to human subjects and data privacy are not applicable. The outcome of this qualitative methodology is the development and synthesis of a structured healthcare workflow specifically tailored for elderly populations, leveraging AI Assistants. This workflow is grounded in the insights and findings extracted from the literature review. It encompasses key components such as medication management, health monitoring, and personalized support, with a focus on enhancing the quality of life and healthcare outcomes for the elderly.

Analysis

Below are some popular applications in the Asian region for monitoring the health and well-being of elderly individuals. There are numerous healthcare apps designed for elderly individuals available in Asia, each offering its unique set of features and benefits. In this section, we will discuss several healthcare apps tailored to senior citizens in Asia. The first one is HealthHub Senior. *HealthHub* is a digital health platform launched by the Health Promotion Board (HPB) of Singapore in 2014 (Luk, 2018). It offers a wide range of health and wellness information and resources for Singaporeans of all age groups, including the elderly.

Several features of HealthHub are particularly relevant to the elderly population. HealthHub Senior, a dedicated section of the platform, offers a wealth of information and resources focused on healthy aging, encompassing topics such as nutrition, exercise, mental health, and managing chronic diseases. Additionally, the Live Well, Age Well program, available free of charge, provides seniors with a diverse range of activities and resources aimed at promoting and sustaining their health and vitality. This program includes exercise classes, informative health talks, and engaging social events. The HealthBuddy interactive tool empowers users to create personalized health plans and diligently monitor their progress, while the Medication List feature assists in medication management, ensuring timely doses through reminders. Furthermore, HealthHub extends its support to caregivers of the elderly through a dedicated Caregiver Resources section, offering valuable insights into care management, financial assistance options, and avenues to connect with support groups (Khow et al., 2021).

Beyond these features, HealthHub offers additional resources like an extensive library of health articles and videos that covers a diverse array of health topics, many of which hold direct relevance to the elderly population. Health tools and calculators provided by HealthHub aid users in tracking their health metrics and making well-informed decisions regarding their overall well-being. Moreover, the platform boasts a comprehensive health directory that facilitates the discovery of healthcare providers in Singapore, streamlining the process of accessing essential care services. Altogether, HealthHub emerges as a valuable and holistic resource, serving as a one-stop destination for elderly individuals seeking information, guidance, and support related to healthy aging, chronic disease management, and caregiving (Listyo, 2023).

The PolyU Health Management App, developed by the Polytechnic University of Hong Kong, serves as an indispensable tool for users seeking comprehensive health management and support (Tong et al., 2017). Tailored to meet the needs of elderly individuals, this application empowers users to proactively manage chronic health conditions and enhance their overall well-being. The app boasts an array of noteworthy features, including the ability to connect to wearable health monitoring devices, facilitating the tracking of vital signs like blood pressure, blood glucose levels, and heart rate. In the event of an anomaly, the app promptly notifies a registered nurse, who then initiates contact with the elderly user to assess their health condition. Additionally, the app offers the convenience of 24/7 nurse interaction through video calls, enabling users to seek immediate assistance and receive real-time evaluations of their physical and mental well-being (Shek et al., 2015). Furthermore, it provides access to a wealth of health education resources, ranging from informative articles and videos to interactive quizzes. A vital component of the app is its medication management system, ensuring users never miss a dose by sending timely reminders and tracking medication adherence. For caregivers, the app offers invaluable support, granting them access to their loved one's health data and providing alerts regarding any abnormal vital signs or medication adherence issues. In sum, the PolyU Health Management App emerges as a comprehensive and user-friendly solution that empowers the elderly to take control of their health and well-being while fostering a sense of security and support within their caregiving network.

The *Clevermind* App is Japan Japan-based mobile application meticulously designed to enhance cognitive function and memory in senior individuals (Berenguer et al., 2016). It stands as a valuable tool particularly tailored to meet the unique needs of older adults. Developed by a team of dedicated researchers and clinicians at the University of California, San Francisco, this app is firmly grounded in the latest scientific advancements in brain health and cognitive training. Clevermind addresses the specific challenges faced by individuals dealing with Alzheimer's disease and various forms of dementia, with the overarching goal of preserving and enhancing their cognitive abilities, thus improving their overall quality of life. What sets Clevermind apart is its diverse array of interactive exercises and games, strategically crafted to target various cognitive domains such as memory, attention, processing speed, and executive function. These exercises strike a delicate balance between being stimulating and achievable, all while being highly personalized to cater to the user's individual needs and abilities. Beyond cognitive workouts, Clevermind employs an array of features aimed at ensuring sustained engagement and motivation. The app offers valuable feedback on performance and diligently tracks progress over time, allowing users to witness their cognitive improvements. Furthermore, it incorporates a system of rewards and incentives, including badges and leaderboards, to incentivize continued participation and achievement. Clevermind thus emerges as a comprehensive and empowering solution, leveraging the latest research and technology to support older adults in preserving their cognitive health and enjoying a more fulfilling life (Chen et al., 2021).

Silver Talkies is an Indian-based application that serves as a thriving social networking platform designed exclusively for seniors, contributing significantly to their wellbeing. It endeavors to foster connections among older adults, facilitating the sharing of stories, advice, and meaningful experiences while also offering a gateway to engaging in a plethora of online events and activities. More than just an app, Silver Talkies embodies a social impact organization, driven by a passionate all-women-led team dedicated to enriching and empowering the lives of individuals aged 55 and above (Samanta, 2020).

The essence of Silver Talkies lies in its diverse range of offerings, each carefully curated to cater to the unique interests and needs of older adults. This comprehensive approach includes a spectrum of virtual and in-person events, from enlightening workshops to enriching classes and vibrant social gatherings, all thoughtfully designed to keep seniors actively involved and connected with their peers. Furthermore, Silver Talkies presents a robust social networking forum, providing a secure and supportive online space where older adults can seamlessly connect with one another, share their life experiences, and build lasting bonds. Moreover, the platform extends its commitment to empowerment by serving as an engagement and opportunities hub, offering avenues for older adults to remain actively engaged, be it through volunteering initiatives, exploring second careers, or receiving invaluable assistance in financial planning. Silver Talkies embodies not just an app but a vibrant community and a lifeline for seniors, fostering a sense of belonging, purpose, and fulfillment in their golden years (Silvertalkies, 2023).

Snug Safety is an essential application designed to provide a daily check-in service specifically tailored for seniors living alone. This invaluable tool offers a profound sense of security, assuring both seniors and their families that someone is consistently looking out for their well-being (Andrews et al., 2021). Snug Safety is accessible to a wide range of users, and it is completely free to use. The functionality of Snug Safety is straightforward yet incredibly effective. At the time of choosing each day, the Snug app will prompt the user with a notification. With a simple tap of a button on a mobile device, users can confirm users well-being. However, if circumstances prevent the user from checking in by the user designated time, the vigilant Snug dispatcher will promptly reach out to the user, ensuring user safety. In cases where the user remains unresponsive, user-pre-designated emergency contacts will receive alerts, and if necessary, emergency services will be swiftly summoned for a wellness check. For added convenience and peace of mind, Snug Safety also enables family members to utilize the app to contact the appointed personal dispatcher at any time, should the user experience an emergency. Snug Safety stands as a robust, user-friendly, and proactive solution that empowers seniors to maintain their independence while ensuring they are never truly alone in times of need (Snugsafe, 2023; Anshari et al., 2023b).

Discussion

From the literature review analysis, a healthcare workflow for AI Assistants for the elderly group is obtained. Elderly using AI assistant devices for healthcare workflow refers to the integration of AI technology in healthcare settings to assist and support elderly individuals in managing their health and well-being. This workflow involves the utilization of AI-powered devices or applications designed specifically to cater to

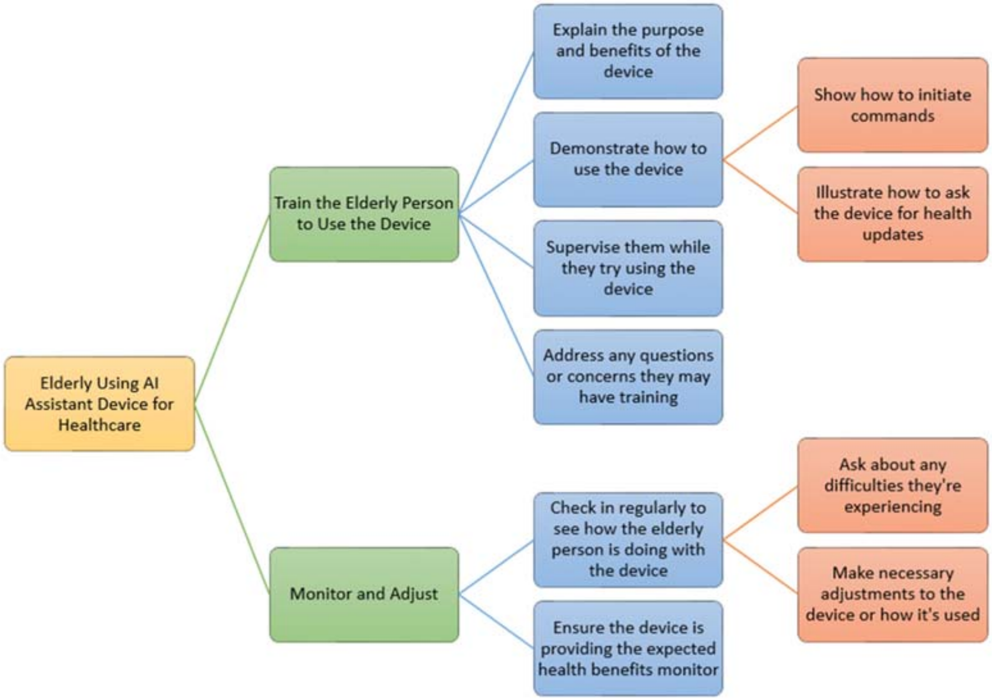

Figure 14.1 Elderly using artificial intelligence assistant device for healthcare workflow.

the unique needs and challenges faced by older adults in terms of their healthcare (see Fig. 14.1).

Process 1 involves the crucial initial steps of introducing the elderly individual to an AI assistant device designed for healthcare support. This training process begins by elucidating the device's purpose and elucidating the myriad benefits it can bring to their health and well-being. Subsequently, a hands-on demonstration unfolds, illustrating the device's functionality in initiating commands and soliciting health updates, all designed to empower the elderly user. During this phase, diligent supervision ensures their comprehension and proficiency, and any queries or concerns that may arise are thoughtfully addressed, fostering a sense of confidence and readiness to use the device. This comprehensive training regimen is encapsulated by the training, underlining its significance in the healthcare workflow.

Process 2, aptly named "Monitor and Adjust", takes place after the elderly individual has been trained in device usage. It entails periodic check-ins to gauge the elderly person's ongoing experience with the AI assistant device. These check-ins are characterized by open-ended inquiries about any challenges or difficulties encountered while employing the device. Moreover, the healthcare team stands prepared to make necessary adjustments, either to the device itself or the manner in which it is employed, ensuring it consistently delivers the anticipated health benefits. This vigilant and responsive monitoring process is emphasized monitor, signifying its pivotal role in the continuum of healthcare support for the elderly.

Developing a workflow for elderly healthcare using an AI assistant device is a commendable initiative, but it comes with its fair share of challenges. First and foremost is the critical concern of privacy and security, as handling sensitive health data demands rigorous safeguards and compliance with healthcare data regulations. Designing a user-friendly interface is also paramount, given that elderly users may not be technologically proficient; the interface must be intuitive, accommodating features like large fonts, voice commands, and simplified user interfaces. Additionally, integrating the AI assistant with existing healthcare systems, electronic health records, and various wearable devices can prove complex and necessitates cooperation from diverse stakeholders in the healthcare ecosystem. Furthermore, ensuring data accuracy, device compatibility, and personalized recommendations tailored to individual health conditions are essential aspects of development. Ethical considerations, data quality, and the accessibility and affordability of the solution for elderly individuals also present significant challenges. Continuous monitoring, improvement, and building user trust round out the multifaceted task of creating an effective and reliable AI healthcare assistant for the elderly, requiring collaboration across disciplines and ongoing user feedback.

The latest trend in digital health technology that will be widely developed to assist the elderly in the coming years is the use of Digital Twin for the elderly. Digital Twins for the elderly serve as virtual replicas, leveraging real-time data from various sources to monitor and enhance the well-being of older individuals. These innovative digital counterparts play a pivotal role in health management by continuously tracking vital signs and health metrics through wearable devices and sensors. The technology extends beyond health monitoring, incorporating features such as activity tracking, medication management, and remote assistance. By analyzing daily routines, sleep patterns, and exercise habits, Digital Twins provides valuable insights for caregivers and healthcare professionals to assess overall health. Additionally, they contribute to cognitive support through memory aids and interactive exercises for those facing cognitive challenges. Socially, Digital Twins enable connectivity by integrating with communication tools, reducing feelings of isolation. Predictive analytics based on long-term data facilitate early detection of health issues, supporting preventive measures and personalized healthcare planning. Moreover, Digital Twins can optimize the home environment by integrating with smart technologies, ensuring comfort and safety. Ultimately, the objective is to empower the elderly to age in place while providing caregivers with actionable insights for tailored and timely care.

Conclusion

In conclusion, this research highlights the potential of AI in improving healthcare for older people in Asia. The AI assistant device workflow involves two main processes:

"Training" to help seniors understand and use the device effectively and "Monitor and Adjust" to provide ongoing support and make necessary improvements. This approach can bridge the generation gap and empower elderly individuals to take control of their health in an ever-changing healthcare landscape. By embracing AI, we can create a healthcare system that better serves the needs of older adults, ultimately enhancing their quality of life in Asia and beyond. This research provides a practical framework for developing AI assistant devices for elderly healthcare, promoting digital inclusivity and well-being.

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CHAPTER 15

Digital transformation of healthcare services and infrastructure in Asia: the metaverse bound?

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Introduction

The world is moving towards an era where digital healthcare is not a trend but a reality (Jedamzik, 2019; Wong and Sa'aid Hazley, 2020), leading to major changes in the delivery, accessibility, and performance of global healthcare (Ali et al., 2023). Diverse state-of-the-art technologies such as *artificial intelligence* (AI) (Ullah et al., 2023), *telemedicine* (Tajudeen et al., 2022), *mobile service applications* (Chua et al., 2023), *wearable devices* (Kasoju et al., 2023), *robot technology* (Wagner & Borycki, 2022), *virtual reality* (VR), *augmented reality* (AR), *blockchain*, and many other cutting-edge digital technology had radically changed the traditional healthcare worldview (Ullah et al., 2023).

This monumental shift has enhanced the efficiency and efficacy of healthcare services and fostered an innovative environment and advanced patient-centric care (Stoumpos et al., 2023). The adoption and development of digital healthcare technologies have significantly impacted the healthcare ecosystem, especially in Asia as a context, mainly due to growing urbanization, rising population in general, and an increasing number of chronic diseases in the region (Baur et al., 2021).

The emergence of innovative technologies in digital healthcare and the unique demographic and healthcare challenges in Asia have potentially contributed to an opportunity to transform the healthcare industry holistically (Junaid et al., 2022). Notably, this transformation revolves around state-of-the-art technologies to optimize accessibility, quality, and long-term sustainability seamlessly (Junaid et al., 2022). Noteworthily, it becomes imperative to examine in-depth the ever-evolving trends that have defined the trajectory of healthcare services and infrastructures in Asia. The following sections explore the revolutionary potential of significant digital healthcare technologies in the Asian context, focusing on the accessibility of healthcare, patient care, and the advancement of infrastructure.

Digital Healthcare in Asia and Gulf Region for Healthy Aging and More Inclusive Societies
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Many revolutionary pillars are the leading edge of technological advancement in the healthcare industry, transforming traditional healthcare practices and establishing the foundation for an era highlighted by technological progress, reliability, and provision of patient-centered care services (Baur et al., 2021). Navaz et al. (2021) highlighted that several digital healthcare technologies, such as AI, robotics, VR, AR, wearable technologies, and blockchain, have been enabling such transformation. However, the cohesiveness of healthcare systems contributes to healthcare delivery and has allowed patients to seamlessly engage in their well-being, promoting an innovative and comprehensive means of management healthcare (Navaz et al., 2021).

Therefore, digital healthcare technologies signify an essential milestone in rediscovering healthcare accessibility, quality, and sustainability (Ali et al., 2023). Asia is now at the forefront of implementing and adapting digital healthcare technologies (Wong and Sa'aid Hazley, 2020), which will lead to significant shifts in the healthcare industry worldwide. This growth prepares Asia to establish new norms for healthcare excellence and resilience (Baur et al., 2021). Hence, it leads to a future where technology and sustainability intersect, resulting in the successful adoption of digital healthcare.

The growth and trend of digital healthcare

An exploration of digital healthcare technology trends consisting of AI, robotics, VR, AR, wearables, and blockchain seeks to shed light on the transformative potential of these technologies in the healthcare industry, which the following sections endeavors to offer insights into the promising future of the healthcare industry, driven by integrating innovation, technology, and a particular emphasis on patient-centered treatment.

Artificial intelligence

AI, as defined by Dave and Patel (2023), refers to the advancement of computer systems equipped to execute actions usually involving human intelligence, including perception, reasoning, and decision-making. In the healthcare industry, AI typically analyses vast amounts of patient data, including medical records, diagnostic tests/scans, and laboratory results, improving clinical decision-making, and optimizing patient satisfaction (Gala & Makaryus, 2023). AI has changed healthcare operations, clinical decision-making, and advanced patient-care treatment by applying advanced algorithms and data analytics, paving the way for a new era of data-driven and proactive healthcare management (Dave & Patel, 2023; Gala & Makaryus, 2023).

In Asia, incorporating AI into the healthcare industry has resulted in notable advancements in various domains, including disease diagnosis, treatment planning, and predictive analytics (Alowais et al., 2023). Implementing AI-driven diagnostic technologies has significantly improved the precision and efficiency of disease detection (Kumar et al., 2023). This empowered healthcare professionals to promptly diagnose and address patients' early illnesses, improving patient prognosis and increasing survival rates (Kumar et al., 2023).

In addition, using AI in treatment planning has significantly transformation in the development and delivery of personalized treatments (Secinaro et al., 2021). Secinaro et al. (2021) add that the approach considers patients' factors, including genetic predispositions, dietary habits, and environmental effects; hence, positive results have been shown regarding patient satisfaction, utilization of resources, cost reduction, and overall success of healthcare delivery.

Further, Dave and Patel (2023) mentioned that AI was pivotal in developing various predictive analytics systems. These systems are designed to forecast healthcare trends and results, allowing healthcare professionals to take preventive steps in addressing illnesses and effectively managing resources (Gala & Makaryus, 2023). Additionally, using AI-driven predictive analytics allows healthcare practitioners the ability to determine populations at risk of a potential disease outbreak, such as COVID-19 (Sarker et al., 2021). Early detection of possible diseases enables the implementation of preventive measures that can effectively mitigate the risk of transmission to a significant degree therefore, have a great possibility of reducing cases by a high percentage (Gala & Makaryus, 2023; Sarker et al., 2021).

It is undeniably true that using AI in the healthcare industry offers numerous ways to enhance human performance (Davenport & Kalakota, 2019). To begin with, AI was designed to efficiently analyze extensive amounts of data, particularly unstructured data stored in electronic health records (EHRs), beyond the capabilities of human clinicians (Asan et al., 2020). A sophisticated AI system can extract relevant data from offline and real-time sources of information, improving the productivity of organizations and assisting healthcare professionals in developing immediate solutions (Asan et al., 2020).

Besides, AI systems demonstrate enhanced precision while performing predetermined tasks. In contrast to human performance, AI can maintain a continuous state of activity without experiencing burnout, ensuring constant performance levels. Moreover, studies instances such as the success of AlphaStar, an AI bot that defeated an elite gamer in a video game (Google DeepMind, 2019), and the achievements of LYmph Node Assistant. It is an AI system that accurately diagnoses breast cancer from lymph node biopsy scans (Liu et al., 2019), attest to the effectiveness of AI-powered decision-making across varied disciplines (Asan et al., 2020; Davenport & Kalakota, 2019; Secinaro et al., 2021).

Implementing AI into the healthcare industry has significantly transformed the way healthcare services are administered and delivered in a context such as Asia. This aforementioned development has cultivated an environment prioritizing innovation, efficiency, and patient-oriented care and potentially drives toward an accessible and technologically advanced healthcare practice.

Robotics

The healthcare sector in Asia experienced significant changes with the extensive adoption of robotic technology, as highlighted by Kaiser et al. (2020). The global health emergency—the COVID-19 pandemic, led the entire region to thoroughly re-evaluate robotic technology's role, particularly in its capacity to help prevent bacteria and viruses (Ullah et al., 2023). Furthermore, there is a growing need for service robots in the healthcare sector (Holland et al., 2021), collaborating with nurses and healthcare professionals to boost productivity (Kaiser et al., 2020), reducing direct human contact (Ullah et al., 2023), and alleviate the shortage of healthcare workers which resulted from the highly contagious nature of disease.

Robotic technology promises to deliver sustainable and cost-effective healthcare solutions while potentially maintaining high patient care standards (Holland et al., 2021). For example, in the study conducted by Yagi et al. (2023), integrating robotic technology for spinal care treatment resulted in precise diagnoses to perform complex spine surgery, hence improving patient care. Besides that, surgical robotic technologies, also known as *assistive surgery* (Pradhan et al., 2021), guided by expert surgeons, can perform minimally invasive surgeries. One example of a notable intervention practice in healthcare is the *da Vinci Surgical Robot* (Bradford Teaching Hospitals NHS Foundation Trust, 2022), which performs minimally invasive surgery on patients with urology, bladder, kidney, and head and neck cancers. As a result, shorter hospital stays due to the precision of accurate surgery and fewer complications in the procedure (Pradhan et al., 2021).

Beyond surgical robotic technologies, robotics has also transformed patient care and support, especially in older adult care (Miyagawa et al., 2020). A notable example is Miyagawa et al. (2020) study of an assistive robot called Pepper, a humanoid robot designed to care for older adults in Japan. Bot-provided care, such as Pepper, is intended to interact with older adults, facilitating communication to maintain their social activities, particularly for those with dementia (Miyagawa et al., 2020). However, there are setbacks; Miyagawa et al. (2020) stated that older adults may experience harmful physical contact as Pepper built to move, which Pepper could not control regarding physical assessments. Therefore, future developers of assistive robotics may need to prioritize safety management concerns.

The integration of robotics into the Asian healthcare sector is revolutionizing the delivery of healthcare, introducing an era of precision, efficiency, and quality care services. This transformation highlights Asia's commitment to leveraging technological advancements to improve patient outcomes and experiences (Kaiser et al., 2020). Robotic technology has enabled healthcare providers to deliver more accurate diagnoses, conduct less invasive surgical procedures, and provide personalized patient care (Pradhan et al., 2021). As robotic technology continues to evolve, its impact on healthcare in Asia will only grow. Implementing robots in healthcare can significantly improve the delivery of healthcare services, enhance the *quality of treatment among patients* (Ullah et al., 2023), increase *overall healthcare outcomes* (Holland et al., 2021), and improve *cost-effectiveness* (Pradhan et al., 2021; Yagi et al., 2023).

Virtual reality

VR is widely acknowledged as an innovative technology with the potential to bring significant advancements across multiple sectors, notably the healthcare sector (Kouijzer et al., 2023). Kouijzer et al. (2023) highlighted that VR enabled an enormous shift in healthcare practices, including patient care, treatment, and healthcare professionals' training. Besides, VR increases the potential for diagnosis, treatment, therapy, and healthcare training by involving individuals in stimulated environments (Kamińska et al., 2022). The following section explores VR's profound impact and practical application within the healthcare industry.

Improvements in diagnostic

Previous studies have shown the effectiveness of VR technology in diagnosing a range of diseases, with a particular focus on cardiovascular diseases (Kim et al., 2020; Kuzu et al., 2023). Through VR, healthcare professionals can closely monitor crucial indicators like heart rate and rhythm, blood pressure, and other vital functions, leveraging this information to enhance the treatment of cardiovascular patients (Kim et al., 2020). Additionally, recent studies indicate that VR technology not only assists the diagnosis and treatment of heart diseases but also demonstrates a preventive effect against factors that pose a risk to cardiovascular health, among which are obesity, hypertension, and high cholesterol levels (Kuzu et al., 2023). Therefore, VR technology enhances healthcare practices by aiding healthcare professionals to visualize better and understand sophisticated anatomical components and disease mechanisms (Al-Khalifah et al., 2006). This, in turn, contributes to the immediate detection of diseases and enables more accurate diagnosis (Kukla et al., 2023).

VR-based treatments

VR holds the potential to confer benefits, especially to those grappling with mental health challenges such as anxiety, depression, substance abuse, and eating disorders (Al-Khalifah et al., 2006). Yeung et al. (2021) emphasizes that the implementation of VR as a therapeutic tool has successfully treated many phobias and posttraumatic stress disorder patients in recent years. Yeung et al. (2021) also highlighted the numerous benefits of using VR instead of traditional therapy. Notably, Hawajri et al. (2023) carried out an investigation that demonstrated the successful use of virtual reality exposure therapy (VRET) in managing anxiety disorders and syndromes.

Through VRET, patients are gradually exposed to triggered anxiety stimulation, enabling them to confront their issues in the absence of the common defensive mechanisms that typically present in such circumstances. As a result, patients learn to reassess the probability of adverse outcomes, offering a substitute for direct exposure to real-world situations (Hawajri et al., 2023). Freeman et al. (2017) outlined a few principal VR objectives within the mental health domain. These objectives include evaluating symptoms, indicators, or associations and exploring probable cause variables. By leveraging VR technology, overcoming the limitations of traditional mental health diagnostics is possible. These diagnostics mainly depend on recollection via clinician interviews and validated questionnaires, prone to human subjectivity and the questionable reliability of memory (Freeman et al., 2017).

Consequently, VR possesses the potential to fundamentally transform the approaches employed in the diagnosis and treatment of mental health conditions (Yeung et al., 2021). Additionally, it offers an opportunity to enhance our understanding of the environmental elements that contribute to mental health problems while also taking into consideration the distinctive differences in adverse psychological responses among individuals (Al-Khalifah et al., 2006; Freeman et al., 2017; Hawajri et al., 2023). As a result, many studies highlighted the effectiveness of VR-based therapies in treating many mental and physical disorders.

Healthcare training

The practical benefits of VR technologies in training healthcare professionals, especially doctors (Kamińska et al., 2022) and nurses (Chen et al., 2020), have been well-documented. These technologies provide virtual stimulations designed to accommodate realistic healthcare circumstances and mimic the execution of complicated operations such as surgery, thereby creating an immersive learning environment (Antón-Sancho et al., 2022). One notable example is the Physical Heart Model. This software presents a detailed virtual stimulation of the anatomical anatomy of the human heart (Alfalah et al., 2018), which allows users to interact virtually with the autonomic structure and mimics a real-life operation (Seo et al., 2017). Noteworthily, Ohtake et al. (2022) reported that the LapPASS simulator, designed to train surgeons in performing laparoscopic surgeries, successfully improved actual surgical outcomes by reducing errors during these procedures (Yang et al., 2018). These instances collectively provided the immense potential of VR in multifaceted healthcare operations.

Augmented reality

The concept of AR, which involves incorporating interactive, real-time digital content into the physical environment, has gathered noteworthy attention in computer science and engineering in recent years (Liao et al., 2020), in contrast to VR technologies, which a computer-generated artificial recreation of users' experience of reality

(Zainal et al., 2022), AR allows for the projection of digital content onto real-world settings, thereby enabling diverse applications (Liao et al., 2020). Many AR interventions exist in the healthcare sector. One study highlighted that AR intervention in the healthcare sector enhances service delivery via AR mobile applications such as *Exergames*, which combine video games with exercise to promote health behaviors (Liao et al., 2020). As a result of the AR-enabled intervention has resulted in an increased success rate in assisting individuals to maintain fitness levels and lower the risk of obesity. Another study by Ara et al. (2022) showed the current trends of AR-enabled in the healthcare industry, as shown in Fig. 15.1.

In a systematic literature review study conducted by Rodriguez-Abad et al. (2021) the study highlights the promising growth of AR within the healthcare domain. Notwithstanding this positive trend, the study identified persistent challenges related to data security, regulatory compliance, and the imperative for standardization within the AR framework (Rodriguez-Abad et al., 2021). Simultaneously, AR is transforming the healthcare sector by improving the precision of surgical procedures, enhancing medical educational and training development, and improving patient care outcomes (Dhar et al., 2021; Zainal et al., 2022). These innovative AR technologies signify

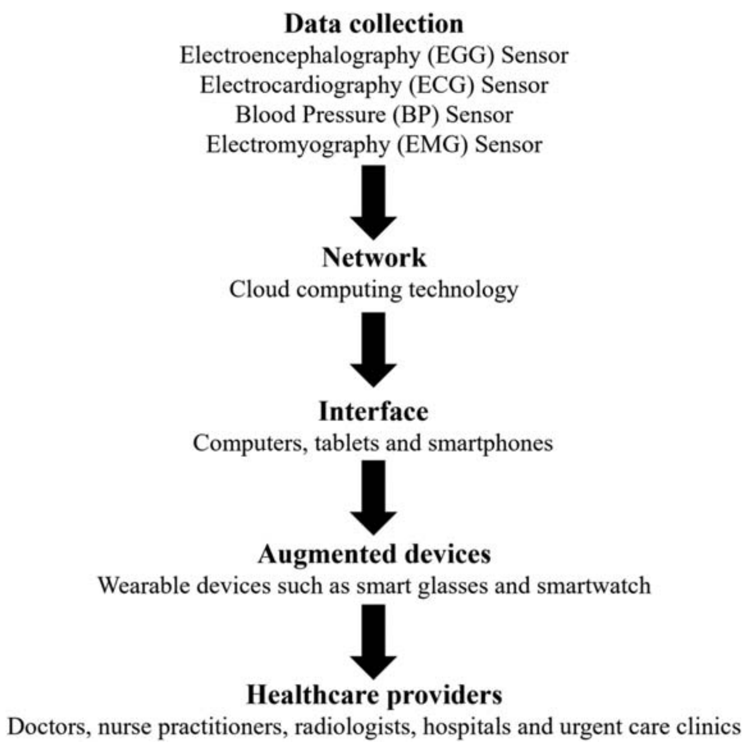

Figure 15.1 Augmented reality in today's healthcare industry.

ongoing trends and developments in AR that promise a future where technology plays a central role in providing more efficient, personalized, and accessible healthcare services (Mahajan, 2021). Therefore, today, studies focused on improving AR technology in the healthcare sector have increased significantly.

Wearables

Devices that can be conveniently worn on and off the body or seamlessly integrated into clothing and accessories fall under the category of wearable technology, commonly referred to as "wearable devices" or simply "wearables" (Smuck et al., 2021). Wearable technology has revolutionized the healthcare sector, offering innovative solutions for monitoring, diagnosing, and managing various health conditions. These wearable technologies, ranging from smartwatches and fitness trackers to advanced biosensors, provide real-time data collection and analysis, enabling both patients and healthcare professionals to establish informed decisions and take proactive measures to improve health outcomes (De-La-Fuente-Robles et al., 2022).

Wearable devices with embedded sensors can provide continuous monitoring of vital indicators, such as pulse rate, blood pressure, and body temperature, allowing healthcare professionals to remotely track patients' health statuses (De-La-Fuente-Robles et al., 2022; Escobar-Linero et al., 2023). This continuous monitoring facilitates early detection of health irregularities and enables timely intervention, particularly for individuals with chronic conditions. Therefore, wearable technology facilitates seamless communication between patients and healthcare providers, enabling virtual consultations, remote monitoring, and telehealth services (Escobar-Linero et al., 2023).

The COVID-19 pandemic normalized physical distancing, making telemedicine crucial to maintaining healthcare quality (Escobar-Linero et al., 2023). Hence, developers are encouraged to design mobile applications that allow users, particularly older adults, to stay updated with their health via smartphones (Chua et al., 2023; Tang et al., 2022). Patients can transmit their health data to healthcare professionals in real-time (Tajudeen et al., 2022), enabling timely interventions and reducing the necessity for frequent in-person visits (Chua et al., 2023). In the study by Tajudeen et al. (2022), an illustration delves into the adoption of mHealth among older adults. The mHealth application facilitates users in storing medical records, drug information, and other pertinent data on their smartphones, fostering a sense of accountability among older adults for their health management (Chua et al., 2022; Tajudeen et al., 2022).

Recent studies have shown that the benefits of telehealth and telemedicine via mobile applications enhanced patients' self-management of their health activities (Tajudeen et al., 2022), mainly promoting mobility among older adults (Chua et al., 2023). For instance, the *TakeMe* app (Chua et al., 2022; Chua et al., 2023; Tang et al., 2022) serves as such an example. However, privacy and data sharing remain persistent challenges for wearable technologies, as highlighted by various studies (Canali et al., 2022; Chua et al., 2023; Tajudeen et al., 2022; Tang et al., 2022).

Blockchain

Ten years ago, Satoshi Nakamoto created blockchain technology as "a peer-to-peer electronic cash system" within the financial services sector, initially known as a cryptocurrency, now commonly referred to as Bitcoin (Anjum et al., 2020). Blockchain technology has reshaped various healthcare applications' data management and governance environments (Anjum et al., 2020; Khezr et al., 2019). Its adaptability and ability to organize, secure, and transfer health data and services have been essential in this reinvention; hence, blockchain technology is at the heart of several innovations in the healthcare sector. As proposed by Khezr et al. (2019), blockchain-based advanced healthcare solutions may be theoretically divided into four layers: data sources, blockchain technology, healthcare application development, and stakeholders (refer to Fig. 15.2). This innovative technology has witnessed a notable upward trajectory and expansion within the healthcare sector.

A notable trend involves the extensive uptake of EHRs and health information exchanges based on blockchain technology (Reegu et al., 2023). Healthcare providers and stakeholders increasingly leverage blockchain to create secure and interoperable platforms that seamlessly share patient data across various healthcare entities (Khezr et al., 2019; Reegu et al., 2023). This trend facilitates enhanced collaboration among healthcare stakeholders, encouraging a comprehensive approach to patient care and streamlining administrative processes, ultimately leading to improved patient outcomes (Anjum et al., 2020; Reegu et al., 2023).

According to a recent study (Gruchmann et al., 2023), the adoption of blockchain technology in managing the pharmaceutical supply chain has become increasingly prominent in the healthcare sector. Their study indicates that integrating blockchain technology facilitates better communication, collaboration, and organizational efficiency among diverse stakeholders in the supply chain, resulting in improved productivity and decreased transaction costs. Furthermore, Gruchmann et al. (2023) stated that the potential of implementing blockchain technology might minimize the risks linked to external medicine fraud, as seen in the case of the unlicensed healthcare practices of the *"fake doctor"* in Malaysia (Bernama, 2020). Another study points out the pivotal role of advanced EHR systems in shaping the future of healthcare, with blockchain-based healthcare systems offering benefits such as heightened security, accessible health records, minimized human errors, reduced counterfeit healthcare services, and a patient-centric approach (Thakur, 2022).

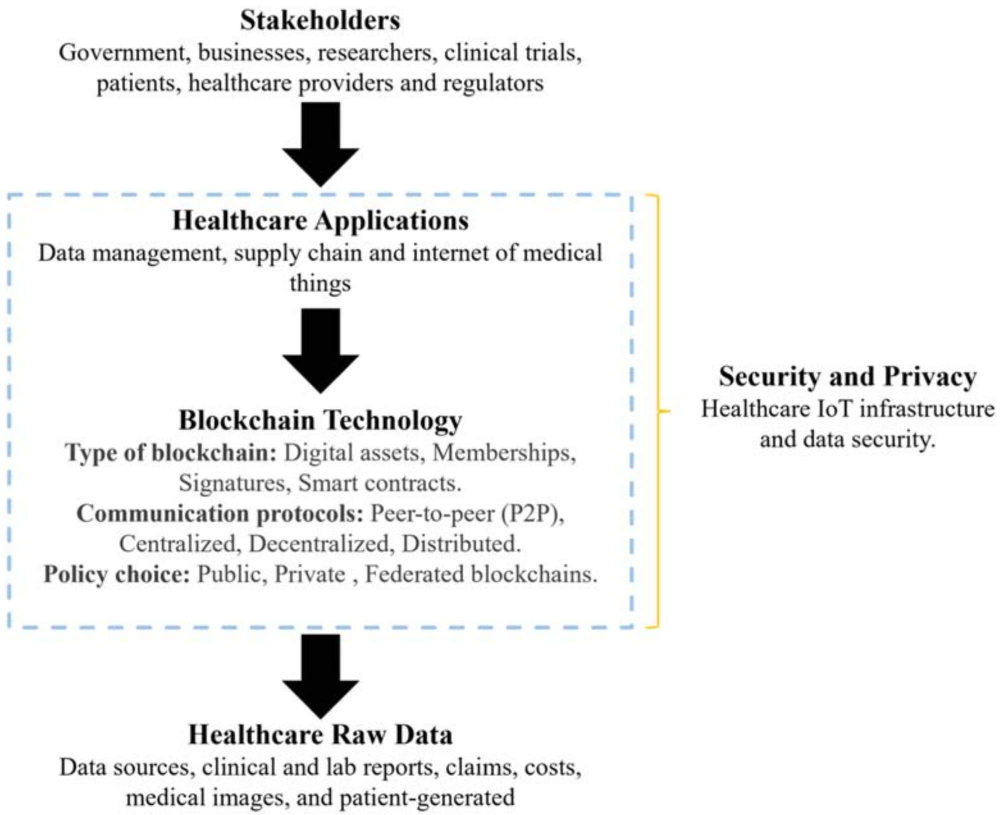

Figure 15.2 An overview of blockchain-based healthcare applications' operations.

As the healthcare industry remains committed to digital transformation and the incorporation of cutting-edge technologies, blockchain technology's trajectory, and expansion are anticipated to play a pivotal role in shaping the future of healthcare provision (Han et al., 2022; Junaid et al., 2022). Blockchain technology influences healthcare delivery by elevating data security, advancing interoperability, and improving transparency and trust (Reegu et al., 2023). This transformative technology is fundamentally altering the paradigm of healthcare service delivery, promising greater efficiency, patient-centric care, and the fortification of resilient healthcare systems (Hussien et al., 2021).

Metaverse at a glance

The word "metaverse" describes a digitally immersive, networked, and virtual environment where individuals may socialize, work, play, and interact (Mystakidis, 2022). Though it's frequently connected to science fiction, technological advancements are making it a more real idea. It envisions a future iteration of the internet characterized by shared, enduring, three-dimensional virtual environments interlinked to form a perceived virtual world. The term "metaverse" combines "meta," indicating beyond, with "universe," depicting a digital space for people to connect, socialize, work, and play. While often linked with science fiction, continuous technological advancements are turning this idea into a concrete reality (Hackl, 2021).

Take OASIS, for instance—an innovative multiplayer online game that swiftly transitions into a lifestyle of its own when metaversified. In other words, it transcends mere gaming, morphing into an all-encompassing online realm where individuals engage in various facets of their lives (Cline, 2023). The metaverse is composed of two integral elements: VR and AR. The metaverse itself is still in its early stages of development. Since it is still developing and taking shape, there is a chance for educators, legislators, and digital designers to be at the forefront of its progress. It's harder to define the word "metaverse." Facebook just rebranded itself using the word "Meta," while Roblox, Epic Games, and Adobe also use it. The metaverse is a fully interactive online environment.

In fact, the metaverse is the culmination of the greatest digital technology available, which can be looked at as a virtual world. A vast array of interconnected digital settings makes up the metaverse, a collective virtual realm. These settings might be 3D virtual worlds, AR, and VR (Adobe, 2022). Individuals can communicate and socialize with one another using digital avatars in the metaverse. It might entail business meetings, educational opportunities, or just hanging out with friends; it's not only about gaming. The metaverse's numerous digital platforms and venues are linked together, making it easy to move between them. Similar technologies or standards like the Metaverse API (MVA) can be used to do this. Users are able to design and personalize their digital personas, settings, and encounters inside the metaverse. Within the metaverse, users may exchange and share this user-generated material.

There is a plethora of possible uses for the metaverse, ranging from gaming and entertainment to education, telemedicine, remote employment, and the arts. VR headsets, AR glasses, cloud computing, 5G networks, blockchain, and AI are some of the key technologies that are facilitating the creation of the metaverse (Hirsh-Pasek et al., 2022). Metaverse is a concept under development. The tech sector is actively developing and debating the metaverse, which is still a work in progress. Enterprises such as Google, Facebook (now Meta), and other startups are funding initiatives connected to the metaverse.

The metaverse is a constantly developing notion that may take years to fully realize. On the other hand, it signifies a potentially revolutionary change in how people communicate with digital devices and one another. Let's have a glance at the benefits of metaverse.

Immersive experiences: The metaverse provides very interactive and immersive digital environments that can improve social interactions, work, education, and entertainment.

Real-time global connectivity: Unlike conventional online experiences, the metaverse allows simultaneous, real-time connection with people while providing a feeling of presence and immersion. It removes physical boundaries to allow individuals to interact, communicate, and socialize in common virtual places.

Innovative applications: By offering fresh and creative methods to interact with users and clients, the metaverse has the potential to completely transform a number of sectors, including virtual commerce, gaming, healthcare, and education.

Enhanced education: Technological developments in VR and AR have enhanced the metaverse's realism and engagement, opening a plethora of uses ranging from teaching and work from home to gaming. Especially for difficult or practical subjects, the metaverse may provide immersive and interactive learning experiences that boost student interest and retention.

Collaboration and remote work: It makes it easier to collaborate and work remotely, which may lessen the need for real office premises and transportation. Within the metaverse, users may experiment with virtual architecture, design, and art as well as express themselves through content creation.

Challenges/concerns in metaverse

Data privacy, security, and digital identity protection are among the issues that the metaverse brings up. Users' virtual assets and private data can be in danger. An overindulgence in the metaverse can result in digital addiction, which has detrimental effects on one's emotional and physical well-being. This covers worries about social isolation, screen time, and sedentary behavior (Statista, 2021).

Due to differences in technology and internet availability, not everyone has equal access to the metaverse, resulting in a separation between those who can and cannot participate. With ambiguous laws governing property rights and ownership, virtual assets and land ownership in the metaverse can result in financial exploitation and speculative bubbles. It can be difficult to distinguish between our virtual and actual identities in the metaverse, which raises concerns regarding our identities and online personas (Cheung et al., 2021).

Dealing with matters such as taxes, intellectual property rights, and metaverse virtual economy regulation presents obstacles for legislators and regulators. With so much user-generated content, it can be difficult to maintain a friendly and safe metaverse environment (Lee et al., 2021). As a result, content moderation is both important and difficult. Excessive time spent in virtual settings has been linked to social separation and isolation from the real world, despite the fact that technology may also promote connections. Extended engagement with VR in the metaverse could potentially lead to mental health issues such as anxiety and depression, alongside physical health concerns like motion sickness and eye strain (Madou, 2022).

The idea of the metaverse is still in its infancy, and how it is developed, governed, and applied in the future will determine how well its advantages and disadvantages are balanced. As the metaverse expands, resolving the issues and optimizing the advantages will be crucial.

Metaverse in healthcare

The idea of the metaverse has a big effect on the healthcare sector in a number of ways. Software programmes are used in evidence-based therapy interventions known as "digital therapeutics" to treat, manage, and prevent disorders related to mental, emotional, and behavioral health (Kim & Kim, 2023). The delivery, demand, funding, and regulatory aspects of healthcare have all undergone substantial change as a result of the COVID-19 pandemic. Consequently, the field of digital medicines has surfaced as a viable and effective means of tackling these transformations. Since more clinical research has been done to assess the possible positive impacts and safety of these digital therapies, digital medicines have undergone a number of stages of evolution and have drawn more and more attention (Park & Lee, 2020).

The incorporation of digital medicines into the metaverse is anticipated to usher in a paradigm shift, rendering their implementation and usage more viable across a spectrum of medical applications, from surgical navigation tools to doctor training. An example of this is found in digital twins—virtual models or simulations of real-world objects, processes, or systems, generated using real-world data and immersive experiences facilitated by VR and AR (Sun et al., 2022). These digital twins facilitate data collection, analysis, and prediction, enabling the integration of extensive patient data for disease progression tracking and personalized treatment strategies.

Telemedicine, a healthcare delivery approach leveraging telecommunications technology, eliminates geographical barriers by providing medical treatments and consultations remotely. Through real-time interactions via video conferencing, mobile applications, and remote monitoring equipment, healthcare practitioners diagnose and treat patients without the necessity of in-person visits, enabling patients to receive care from the comfort of their homes (Freed et al., 2018).

In the realm of medical surgery, particularly surgical training, the metaverse is gaining prominence due to recent technological breakthroughs. Innovations like image-guided intervention, 3D-printed phantoms, and the efficacy of AR visualization in image-guided surgery, as evidenced by the work of Glas et al. (2021), underscore the growing significance. AR technology empowers surgeons to access patient information hands-free by overlaying a 3D virtual model onto the patient's body. Real-time visualization of tumor features and the unique 3D anatomy of each patient is achieved through the synergy of AR technology and patient anatomy, amplifying the safety and efficacy of surgical interventions.

Here are some possible uses and ramifications of the metaverse in healthcare, even if it's still in its early phases of development and adoption:

Virtual consultations and telemedicine: Immersion and interactivity in telehealth encounters can be enhanced via the metaverse. In a virtual setting, patients may confer with medical experts, facilitating instantaneous visual evaluations and diagnosis. Avatars allow for more realistic interactions between patients and doctors.

Physical therapy and rehabilitation: Within the metaverse, patients recuperating from surgery or injuries can perform virtual rehabilitation activities. You may gamify these workouts to increase the motivation and engagement of therapy.

Remote monitoring: Wearables and Internet of Things devices can be incorporated into the metaverse to provide real-time patient health monitoring. Remote monitoring of vital signs, medication adherence, and other health-related data is possible for medical practitioners.

Support for mental health: Immersion settings for mental health therapy and support may be found in the metaverse. It is possible to create virtual environments that support people in managing their stress, anxiety, and other mental health issues.

Accessible healthcare: By removing physical obstacles, the metaverse can improve access to healthcare for underprivileged or isolated communities. Without having to go far, patients may consult with experts and get medical advice.

Gamification of health and well-being: Gamification of virtual environments may be used to promote healthy habits. Rewards and incentives are available to users who uphold good living habits, such as consistent exercise and a balanced diet.

Healthcare professionals may utilize the metaverse to see and analyze complicated medical data, including patient information, 3D medical pictures, and treatment plans. Making better educated judgements and diagnoses may benefit from this. By simulating intricate medical processes and circumstances, virtual environments enable healthcare professionals to hone their expertise. Ensuring the integrity and privacy of data can be assured by employing blockchain technology. Within the metaverse, collaborative research spaces and virtual laboratories could expedite the pace of medication development and medical research. In these shared virtual realms, researchers globally can collaborate, analyzing data and conducting simulations collectively.

Challenges/concerns in metaverse healthcare

It's crucial to remember that, despite the metaverse's enormous promise for improving healthcare, there are drawbacks to consider. These include concerns about privacy, the digital divide, data security, and regulatory compliance. These issues must be resolved as the metaverse develops in order to guarantee the secure and efficient application of metaverse technology in the medical field (Halbig et al., 2022).

Data security and privacy: Because healthcare data is so sensitive, worries regarding data security, patient privacy, and the possibility of data breaches are raised by the metaverse. The healthcare sector is heavily regulated, and the metaverse may have to deal with difficult legal issues pertaining to compliance, licensing, and data protection (Kim & Kim, 2023).

Digital divide: Some people may have restricted access to healthcare services because they may not have access to the technology needed for the metaverse.

Health concerns: Prolonged exposure to VR or AR in the metaverse may cause physical health problems for patients as well as healthcare providers. These problems include motion sickness and eye strain (Madou, 2022).

Ethical and cultural considerations: Since the metaverse can make it difficult to distinguish between actual and virtual identities, it raises ethical concerns concerning the interactions between patients and doctors as well as proper behavior in virtual healthcare environments.

Technology dependability: The stability and dependability of the underlying technologies, such as internet connectivity and VR/AR systems, are critical to the metaverse's efficacy in the healthcare industry (Statista, 2021).

Achieving a successful implementation in the healthcare business would need to address possible obstacles while simultaneously optimizing advantages like enhanced access, education, and support.

Precautions of digital transformation in the metaverse setting

While there are many fascinating prospects associated with digital transformation in a metaverse context, there are also some hazards and hurdles to consider. To guarantee a smooth and safe transfer, it is essential to take preventative measures and deal with these issues (Dwivedi et al., 2015). Here are some safety measures to consider:

Data security and privacy: Make ensuring that strong data encryption and security measures are in place to safeguard private, financial, and sensitive healthcare information. Put robust authentication and access controls in place. Respect applicable data protection laws and rules, such as Health Insurance Portability and Accountability Act and General Data Protection Regulation, and create explicit policies about data ownership and consent (Anthony, 2023).

Cybersecurity: Take precautions against online threats that can impact metaverse users, including phishing, ransomware, and hacking. Regularly update and patch systems and software to address vulnerabilities. Provide comprehensive education to employees and users on recognizing and managing cyber threats.

Identity verification: Establish secure protocols for verifying identity to prevent impersonation and unauthorized access. Enhance identity security by implementing multifactor authentication.

Digital Divide: Recognize possible differences in how people can access the metaverse. Make sure that underprivileged populations are not neglected in the process of digital transformation. Think about granting access to areas and those with lower incomes while also encouraging digital literacy.

Content moderation: To stop hate speech, harassment, and offensive content in the metaverse, content moderation regulations should be established. To implement these rules, use both human moderators and AI-driven moderation technologies.

Safety and health: Users should be advised of the possible health risks—such as eye strain, motion sickness, and health problems connected to VR—that come with prolonged usage of the metaverse. Encourage balanced and appropriate use to avoid detrimental effects on one's physical or emotional well-being (Dwivedi et al., 2015).

Compliance with laws and regulations: Keep abreast of the ever-changing metaverse rules and regulations, particularly as they pertain to the banking and healthcare industries. Assure complete adherence to all applicable industry-specific laws and guidelines.

Ethics and prejudice: Recognize that AI algorithms deployed in the metaverse, especially in the healthcare industry, may be biased. Make sure that decisions made using AI are fair and transparent. Create and abide by moral standards for AI research and use in the metaverse.

Collaboration and commons: Encourage open standards and interoperability to make sure that various metaverse systems may successfully connect with one other. Adopting technologies that facilitate data and content migration or sharing can help you avoid vendor lock-in.

Education and training: Give employees, medical experts, and users thorough training and instruction on metaverse technology, including best practices and any hazards. Promote awareness and ongoing learning.

Customer service and input: Provide support channels for users who could experience problems, worries, or technological problems while using the metaverse. To enhance the metaverse experience, ask users to report issues and offer comments.

Management of change: Establish a strong change management procedure to lead the company through its digital transformation and guarantee a seamless, interruption-free transfer.

Continuity of operations and disaster recovery: Create backup plans in case the metaverse has service disruptions, so that vital medical services and operations can carry on in the event of technical difficulties or blackouts.

Scalability and effectiveness: Consider scalability in order to meet the metaverse's expanding user population and changing technological needs. Organizations may reduce the dangers that come with digital transformation in a metaverse context and make the shift to this cutting-edge virtual environment safer, more secure, and effective by taking some preventative measures.

Case study: Metaversepital—potential of shaping healthcare in metaverse in Asia

Even though the metaverse is still in its infancy, it has the power to transform Asian healthcare and solve a number of the region's healthcare-related issues. Using the metaverse to develop creative medical solutions and increase access to healthcare services is one possible scenario.

Using digital twin and metaverse technology, Chung-Ang University Gwangmyong Hospital in South Korea has established a virtual hospital dubbed "Metaversepital," which enables patients to get medical care and consultations without having to attend the facility. With the usage of the metaverse and digital twin, Metaversepital, a ground-breaking virtual hospital, offers a new paradigm in healthcare delivery by overcoming physical barriers. The goal of Metaversepital, which was created by a team of VR specialists, technological experts, and healthcare professionals, of Chung-Ang University Gwangmyong Hospital is to provide patients all over the world with immersive and easily accessible healthcare experiences (Chung-Ang University, 2022).

Goals

Global accessibility: Metaversepital works to remove obstacles based on geography so that patients may get top-notch medical treatment wherever they are.

Personalized virtual treatment: Metaversepital employs advanced VR and AR technologies to tailor medical treatments, offering a more immersive and personalized approach to healthcare experiences based on individual patient needs.

Medical education and training: Metaversepital is a global center for medical educators and trainers to participate in lifelike medical education and training. This improves their expertise in a risk-free virtual setting.

Features

Virtual consultations: Using AR or VR headsets, patients may make virtual visits with medical professionals. Using virtual interfaces, medical professionals perform thorough evaluations, go over patient histories, perform examinations, and talk about treatment options.

Immersion patient education: To inform patients about their diseases, available treatments, and preventative actions, Metaversepital uses interactive VR modules. In order to better understand their health, patients can interact with three-dimensional simulations of their anatomy.

Virtual wards and recovery areas: Patients receiving therapy or recuperating from injuries can stay in virtual hospital rooms, which provide a calming and adaptable setting to improve well-being. With the ability to remotely monitor patients, healthcare practitioners may guarantee an ongoing feedback loop.

Medical training simulations: For practical instruction and skill development, medical practitioners can access authentic medical scenarios within the metaverse.

Patient satisfaction at Metaversepital has significantly increased as a result of people appreciating the convenience and individualized nature of virtual healthcare, despite challenges with accessibility, affordability, and data security related to protecting sensitive patient information in the virtual world. Improved training opportunities assist medical workers and result in better patient outcomes. The virtual hospital has emerged as a trailblazer in the incorporation of metaverse technology into traditional healthcare, spurring like endeavors throughout the globe.

Conclusion

In the ever-evolving landscape of healthcare, the changes brought about by digital transformation stands as a pivotal force, converging towards the boundless realm of the metaverse. The growth and trends in digital healthcare, spanning the realms of AI, robotics, VR, AR, wearables, and blockchain, form the building blocks of this narrative. These technological pillars collectively sculpt a healthcare landscape that transcends the conventional, propelling the industry into an era of unprecedented possibilities.

Central to our chapter is the elusive concept of the metaverse. A thorough examination of this digital realm reveals its capacity to reshape the fundamental nature of healthcare. The integration of the metaverse in healthcare not only enables patient experiences improvement but also signals the dawn of a new era marked by heightened collaboration, advanced research, and innovative treatment modalities. Yet, with the allure of the metaverse comes the imperative of caution. Precautions in the digital transformation within this setting are paramount. As we delve into the immersive possibilities, safeguarding the integrity, security, and ethical dimensions of healthcare within the metaverse becomes an ethical obligation.

In contemplating the integration of the metaverse into the healthcare sector, it is crucial to recognize that this transformative journey extends far beyond the realm of technological advancement. Beyond the mere evolution of digital tools and platforms, it represents a fundamental restructuring of the foundational principles that underpin patient care. The incorporation of the metaverse not only holds the potential to revolutionize healthcare practices but also to redefine the intricate dynamics of the doctor-patient relationship.

This paradigm shift goes beyond the immediate benefits of technological innovation; it necessitates a broader commitment to cultivating an inclusive and equitable healthcare landscape across the diverse populations of Asia. The emphasis lies in ensuring that the advantages derived from this digital transformation are accessible and beneficial to individuals from various cultural, economic, and social backgrounds. This inclusivity has become a cornerstone in the metamorphosis of healthcare, preventing the emergence of technological divides and disparities in healthcare outcomes.

Examining the case study of "Metaversepital" in South Korea provides a compelling exploration of the latent potential inherent in integrating the metaverse into healthcare systems. By scrutinizing the practical implications of metaverse-driven healthcare practices in a real-world setting, this case study offers a tangible lens through which we can envision the transformative impact on Asian healthcare. It serves as a testament to the feasibility of metaverse-driven healthcare solutions and as a guide for navigating the complexities of implementation, regulation, and cultural adaptation in the diverse healthcare landscapes across Asia. Doing so provides valuable insights into crafting a future where the metaverse is seamlessly woven into the fabric of healthcare, transcending boundaries, and enhancing the well-being of individuals throughout the continent.

The narrative, therefore, culminates in a realization—while the metaverse holds immense promise, a judicious approach, meticulous precautions, and a comprehensive understanding are indispensable for steering the course of digital transformation in healthcare towards a future that is not just virtual but profoundly impactful on the well-being of individuals across Asia and beyond. Navigating this landscape requires a delicate balance between innovation and ethical considerations, with a commitment to shaping a future where healthcare is not just digital but also compassionate and accessible to all.

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SECTION IV

National healthcare visions and digital transformation of healthcare services and infrastructures in gulf region

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CHAPTER 16

The role of big data in healthcare in Gulf region

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Introduction

The increase witnessed by the world in the volume of digital operations through various communication channels has led to an increase in the volume of big data. Big data constitutes huge amounts of data and information that have huge impacts in various fields. Attempts to leverage big data analytics (BDAs) have become a common denominator for all companies (both large and emerging). The first comprehensive study on big data and information was in the year 1997, from this date interest in big data began and its numbers began to be counted. The volume of data produced by the world in 1999 was approximately 1.5 exabytes, while in 2003 it was about 5 exabytes (Jifa & Lingling, 2014). The world now produces a large amount of data amounting to more than 1.7 trillion bytes per minute, some of which are stored and analyzed by some data centers, and some of which are scanned for lack of importance. According to IDC, the global BDAs market was valued at $271.83 billion in 2022 and is expected to grow from $307.52 billion in 2023 to $745.15 billion by 2030.

The term big data is used to describe and define massive data, which appeared in the era of the information explosion. Big data is large, diverse data that is difficult for traditional computer software to deal with, and its users are distinguished by their possession of specialized skills and capabilities.

Big data contributes to the decision-making process in various organizations. To make effective decisions, organizations need effective processes; To convert a large amount of diverse, fast-moving data into useful data. The process of extracting value from big data can be divided into two processes: data management and data analysis. Data management includes the processes and technologies that support the acquisition, storage, preparation, and preparation of data for analysis. As for analysis, it includes the techniques used to process data and gain benefit from it (Gandomi & Haider, 2015). Big data analysis has multiple benefits. Banks and financial institutions can settle cross-border transactions including large amounts in real time; Built-in BDAs enables

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financial institutions to quickly settle transactions, with the ability to monitor and remediate any damages in real time.

Big data is defined from the perspective of technicians as large-scale, fast, highly diverse and innovative assets, in addition to being cost-effective for processing information and improving decision-making. On the other hand, big data is defined as data generated through the use of various digital devices and everything connected to the Internet. It is a very large and complex collection that is regularly generated from new and diverse sources. So that it cannot be easily processed using conventional processing techniques (Ghasemaghaei, 2018).

Big data and the Internet of Things (IoT) have revolutionized healthcare systems. Aceto et al. (2020) found that the use of the IoT and big data in Italian hospitals led to an improvement in the service performance of patients, and then increased their satisfaction with the performance of the health system. Fig. 16.1 Shows what medicine would look like in a typical IoT hospital. In practice, the patient will receive an identification card that, when scanned, stores all the patient's medical information, including test results, medical history, and prescriptions. Doctors and nurses can easily access this record from any tablet or desktop computer.

According to Bilkey et al. (2019), there are sorts of individual characteristics utilized for patient classification in a healthcare setting:

1. Traditional clinical phenotypes;
2. Family history;
3. Environmental and lifestyle factors;

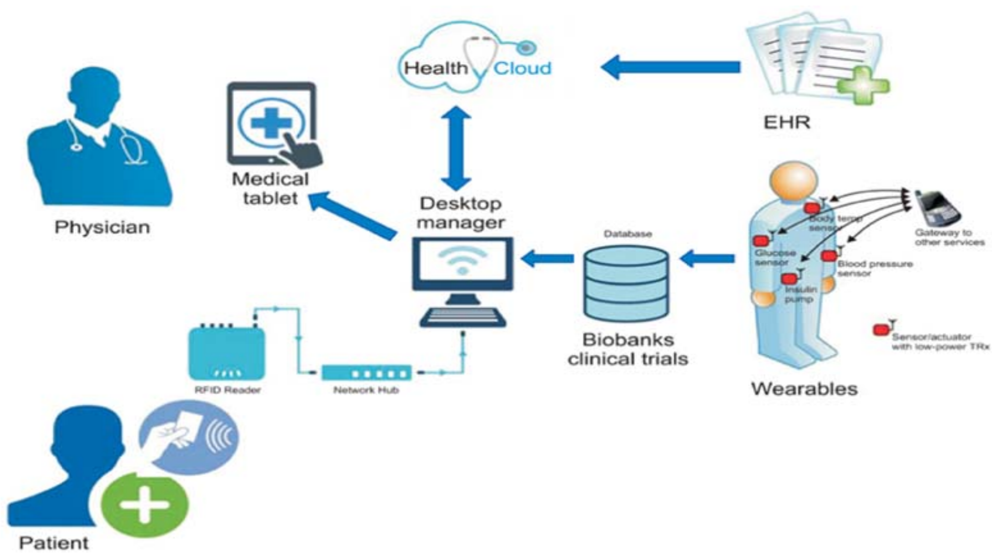

Figure 16.1 Medicine in the IoT Hospital.

4. Invariable patient-specific features (genetic make-up);
5. Variable "omics" properties (cell type-specific and changing over time).

The first two categories of information are routinely documented for each patient in a clinical environment. Environmental and lifestyle data are typically acquired through questionnaires, which are frequently erroneous. Environmental and lifestyle metrics are increasingly available through wearable devices, which are more practical and give more detailed and frequently higher-quality data for PM purposes, while integration with clinical data is still absent.

In recent years, healthcare has changed from a disease-centered model to a patient-centered model. In order to meet the requirements of this model, effective patient-centered care must be provided, so it is necessary to manage and analyze big healthcare data (Senthilkumar et al., 2018). Analysing healthcare data is critical, as it can save lives and improve quality of life (Ukil et al., 2016). Fig. 16.2 shows the growth in big data between 2013 and 2020.

Big data has revolutionized clinical research and disease treatments, helping clinicians to make rapid and accurate diagnoses (Almotiri et al., 2016). The Montalvo says, Head of North America Health Analytics Practice more than ever, organizations are seeing a growing demand for data analytics, to help them make better decisions and improve outcomes. Fig. 16.3 shows the volume of data generated by healthcare applications in North America between 2010 and 2015. Fig. 16.3A total volume of healthcare data, Fig. 16.3B volume of public unstructured data, and Fig. 16.3C volume of electronic health records (EHRs) data (https://www.corporatewellnessmagazine.com/article/big-data-and-the-future-of-health-analytics).

In additional, it is possible to benefit from big data in the field of healthcare by monitoring and studying the activity of patients via mobile devices, which contributes

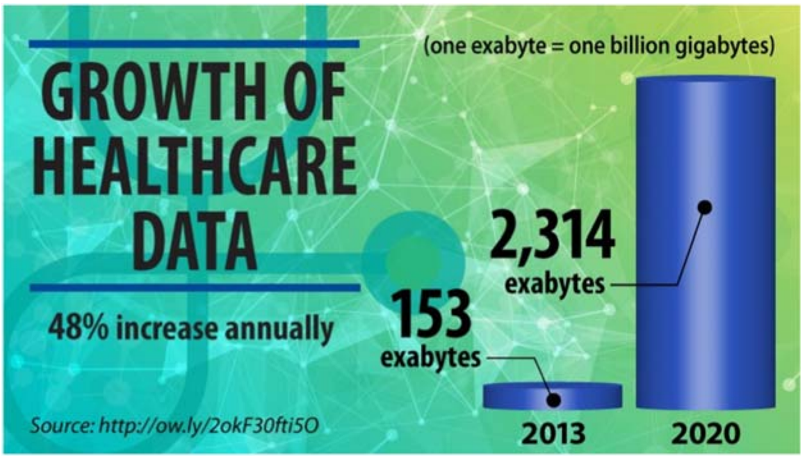

Figure 16.2 The growth in big data between 2013 and 2020.

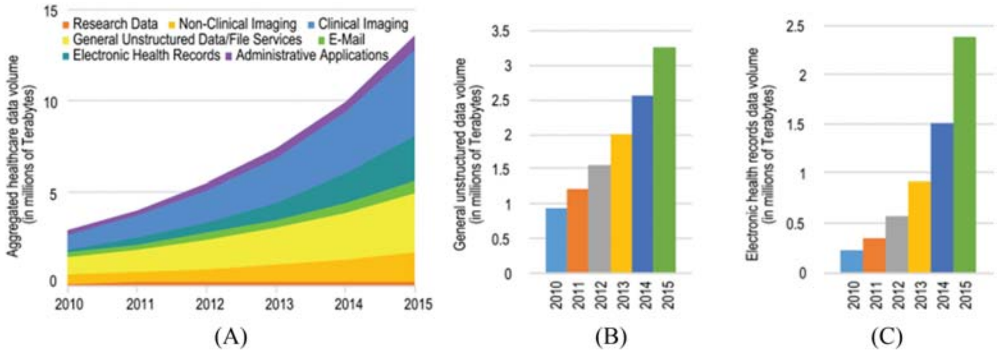

Figure 16.3 The volume of data generated by healthcare applications in North America. (A) Aggregated healthcare data volume; (B) General unstructured data volume; (C) Electronic health records volume.

to a more accurate diagnosis of health conditions, and the possibility of sending information to the doctor for analysis and making the appropriate medical action. The connected devices take the vital data of the body throughout the day to be transmitted wirelessly to the doctor's devices such as computers and smartphones, in addition to enhancing patients' participation and interaction with doctors, which contributes to reducing medical expenses (Abdulshahed et al., 2019). Big data and the IoT have revolutionized healthcare systems. We are moving from ordinary use of technology to more complex technologies generating huge amounts of data. In general, big data can be divided into three forms: structured, unstructured, and semistructured. Structured data is stored and processed in a specific format. It is data that can be easily retrieved and read. As for unstructured data, it faces multiple challenges in terms of processing as well as extracting useful information from it (Wu & Lin, 2018). Healthcare data comes from various sources (medical records, home sensors, examinations, medications, and wearable devices). Muni Kumar and Manjula (2014) argue that the healthcare system generates a large amount of data every day centred on diseases, patients, treatments, and other factors. To manage and process this data more effectively, healthcare units need to use modern methods to provide information that helps in diagnosing the condition of each patient accurately, so most healthcare institutions from the traditional paper-based medical method to the EHRs, which includes an electronic record that includes all medical information about the patient (Alhajaj & Moonesar, 2023). EHRs will be a game changer. Within a short period of time all paper records, often in questionable handwriting, will be replaced by digital records that keep all medical information in one easily accessible place. EHRs have many advantages: First easy access to the patient's complete medical history (medical diagnoses, prescriptions, in addition to any data related to the patient's health condition). Over time, it will reduce redundant and additional medical tests, as well as improve care coordination between healthcare providers and patients (Dash et al., 2019). Second, it helps in faster data retrieval and reporting of quality indicators of healthcare services. Third, also improves public health surveillance by promptly reporting disease outbreaks. Fourth, it helps control the costs of health services.

In the healthcare sector we need to analyze unstructured and semistructured data to take advantage of big data technology extracting and processing big data may be subject to social and legal challenges (Mittelstadt & Floridi, 2016). Based on the above discussion, the current research aims to study the impact of big data on healthcare systems in the GCC countries. The main contribution of this study is that it is the few studies that address big data and healthcare in the Arab world. The main research question is: Does big data affect healthcare systems in the GCC countries?

Characteristics of big data

There are many characteristics of big data (Abbasi et al., 2016; Chen et al., 2015):

- **Size:** The name big data is associated with a huge amount of data. The size of the data plays a very important role in determining the value of the data. Thus, "size" is one of the attributes that must be considered while dealing with big data.
- **Diversity:** Diversity refers to the data source and heterogeneous nature, whether structured or unstructured. Previously, tables and databases were the only sources of data supported by most applications. Nowadays, there are many and varied sources of data, data can be in the form of emails, photos, videos, and so on.
- **Speed:** The term "speed" refers to the speed at which data is generated and processed to meet the requirements of users. Big data velocity deals with the speed at which data flows from sources such as business processes, application logs, networks, social media sites, sensors, mobile devices, etc. The flow of data is massive and continuous.
- **Reliability:** Reliability refers to the accuracy, quality, consistency and credibility of the information collected. Big data makes it possible to collect an indefinite number and in various forms. Therefore, the datasets can be accurate or incorrect. So it is difficult to justify the correctness of the content if we take into account the abbreviations used, slang, spelling errors and so on. However, there are some new technologies being developed by some sites that would make it easier to manage this type of data, especially by W3C.
- **Value:** The concept of value corresponds to the profit that can be obtained from the use of big data. There are a lot of companies that are starting to get incredible benefits from their big data. By understanding and analyzing huge data sets, companies can generate insights and create value that would not be possible through traditional analytics techniques.

Big data challenges

There are many challenges to using big data (Abouelmehdi et al., 2018: Patil & Seshadri, 2014):

- **Volatility:** This refers to the inconsistency that data can show at times, which hinders the ability to handle and manage data effectively.
- **Security vulnerability:** Indicates any problem that could endanger the security or integrity of information. This may include issues accessing sensitive information, data leakage, data corruption, unauthorized access, theft, and malware attacks.
- The biggest challenge facing the use of big data is the employees, and their training. If the employees do not understand the benefits of big data or are unwilling to change the current process methodology in order to adopt it, they will resist it, and thus hinder the progress of the company.
- **Big data unreliability:** Big data is not 100% accurate, because it can contain wrong information, in addition, it can be repetitive, and sometimes it contains contradictions.
- The increase in reliance on big data may lead to a decrease in the number of employees that will be replaced by advanced technology.
- **Data storage:** Health information comes from a variety of sources, including electronic medical records (EMRs), monitoring devices and laboratory tests. Therefore, data storage is a source of concern for many organizations due to data security, because huge data cannot be stored by regular means. Cloud storage is considered the ideal solution to this problem.
- The number of elderly people is increasing, and fertility is declining. Increasing lifespan and declining fertility rates are indicators of the demographic load, which is constantly increasing.
- Healthcare as it currently exists will become impossible within the next 20 years (Thuemmler, 2017). This was clearly demonstrated during the COVID-19 pandemic when healthcare faced a major challenge related to analyzing huge amounts of data and the need to identify trends and predict the spread of the Coronavirus. The pandemic has shown that patients must have access to data, the possibility of digital analysis of this data and access to medical support.

Big data sources

Big data is available from several sources (Blazquez & Domenech, 2018).

1. Resources resulting from the management of a program, whether these programs are governmental or non-governmental. These sources include EMRs, which include total hospital visits, insurance records, as well as banking, food bank and other records.

2. Commercial or transaction-related sources are another source, such as data arising from transactions between two entities, for example, credit card transactions and transactions conducted via the Internet, including through mobile devices.
3. IoT technologies include all devices owned by users, including networks of sensors and tracking devices. For example, satellite imaging, road sensors, climate sensors and tracking data from smartphones, GPS, etc. can be one of the sources of big data.

Impact the big data on the health sector

Health information systems are any systems that capture, store, manage, or transmit information related to individuals' health or the activities of organizations working in the health sector in a fraction of a second and are used to increase productivity and service quality. Big data is playing an important part in healthcare by storing large amounts of data in many file formats and providing fast access to data. EHR is the most widely used Big Data application in healthcare. The main purpose of using big data in healthcare is to improve the services provided to patients, by giving doctors the opportunity to make accurate predictions about the patient's condition based on his clearly and accurately recorded medical history, in addition to algorithms that analyze his lifestyle (Alexandru et al., 2018). The potential of big data to improve health is huge. Every patient has his or her own digital record, which includes demographic information, medical history, allergies, laboratory test results, and so on. Records are shared through secure information systems and are available to both public and private sector healthcare providers. Because each record is made up of a single changeable file, clinicians can make changes over time with minimal paperwork and no risk of data replication. The development in collecting and analyzing data related to therapeutic practices will lead to maximizing the benefit achieved for the patient, through the parallel improvement of cost effectiveness and the quality of health services.

In the healthcare program, big data sources include hospital records, patient medical records, medical examination results, and devices that are part of the IoT (Dash et al., 2019). Medical research centers also generate an important part of big data related to healthcare. In order to benefit from this data, healthcare program providers must be fully equipped with the appropriate infrastructure to manage and analyze data systematically in order to extract useful information in the development of healthcare programs. By integrating biomedical data and healthcare data together, health organizations can revolutionize medical treatments. In addition, BDAs can be used to treat some special cases. For example, some types of medical treatments (especially those that can be worn continuously) require continuous follow-up of the patient's condition, continuous recording of patient data, and a high speed of processing the case. Therefore, web/mobile applications have been expanded to enable patients to quickly and immediately send their signs and symptoms to the healthcare provider in case they encounter any health problem (Awrahman et al., 2022). On the other hand, in the follow-up of the elderly who suffer from various diseases. Many countries have begun to use big data technologies to deal with and manage cases of the elderly. For example, the European Union is facing many changes that may affect the sustainability of its healthcare system. By 2025, the average life expectancy of the population is expected to increase. This may lead to more people living longer, but not necessarily with a new health condition, many of whom are likely to suffer from various health problems. This will lead to more pressure on healthcare costs and economic productivity in Europe. In this context, health-related big data can have a positive impact on healthcare in European Union countries. Big data can help in making healthcare decisions, through:

- The possibility of disease prevention by identifying risk factors for disease.
- Improving pharmacovigilance and patient safety through the ability to make more accurate medical decisions based on information provided directly to patients.
- Predictability of results.

Previous studies

BDAs has previously been extensively researched in research (Hayek et al., 2022; Hayek, 2022; Nora et al., 2022). Alhajaj and Moonesar (2023) argue collecting and analyzing data has become critical for many industries, including the healthcare industry, where a large amount of data is generated on a regular basis. The volume and complexity of these data grow significantly with time. As a result, it is classified as large data, which cannot be easily stored or evaluated unless modern technologies are used. Recent technological advancements have shown new chances to use big data analysis to follow a patient's record and health. Nonetheless, it has created new hurdles in terms of ensuring data privacy and security in the healthcare business. The researchers aim to offer new researchers with insights into big data use in healthcare systems and its concerns, as well as to advise academics interested in researching the potential and addressing the obstacles of big data implementation in emerging nations such as the United Arab Emirates (UAE). This study employs a systematic technique to investigate the role and efficacy of big data in UAE healthcare. This research employs the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) technique for reporting reviews and analyzing randomized trials. The Critical Appraisal Checklist for PRISMA 2009 was also used in the research. The study indicates that big data can improve healthcare systems in the United Arab Emirates; nevertheless, country authorities must realize the construction of efficient frameworks for performance, and quality assessment of the new healthcare system is critical. The stated goal can be met by combining big data and health informatics with the assistance of IT specialists, healthcare managers, and stakeholders. The most often cited concerns were data privacy, data storage, data structure, data ownership, and governance. El Khatib et al. (2022) discussed the most important opportunities and challenges facing the application of big data in the healthcare sector in the UAE, in addition to evaluating the methods used in analyzing medical data. The results showed that healthcare systems in most regions of the UAE are still slow in adopting digital transformation, and the matter is still in its initial stages. Batko and Ślęzak (2022) Examining the usability of BDAs in healthcare. The direct research was conducted based on a questionnaire distributed to 217 medical facilities in Poland. The results showed that BDAs can bring many benefits to medical facilities. In addition, companies in Poland are moving toward big data-based healthcare and use structured data and unstructured data in their work. Al-Aswad et al. (2021) proposed a blockchain-based zero-knowledge proof model, which is a patient-centric IoT-based model. The model ensures patients' informed consent before accessing their health data including their health status. In addition, the model provides interoperability between different stakeholders by providing reliable communication of medical data. In addition, it ensures the robustness and integrity of data using the immutability features of the blockchain. The study found that the use of blockchain provides many opportunities for healthcare in Bahrain, leading to increased availability of healthcare data. However, several technical and regulatory challenges must be addressed before Bahrain's healthcare sector can adopt a blockchain-based model of healthcare. Qaffas et al. (2021) discussed the impact of the IoT and Big Data on healthcare in Saudi Arabia. The study showed that the application of the IoT and Big Data technologies can be very useful in reducing the risks resulting from not diagnosing many diseases such as high blood pressure and other chronic diseases. The results showed that age and diabetes play a very important role in diagnosing high blood pressure in the elderly. It was also found that the risk of developing high blood pressure due to smoking is less than the risk of developing diabetes, and older people should eat smaller amounts of salty foods. Moreover, it was found that support vector machine techniques gave better results than C4.5. Imran et al. (2021) stated that BDAs in healthcare, for example, can help determine disease causes, generate effective diagnoses, improve QoS guarantees by increasing the efficiency of healthcare delivery and the effectiveness and viability of treatments, generate accurate predictions of readmissions, improve clinical care, and identify cost-saving opportunities. Based on the findings of a systematic literature study, The researchers give a detailed roadmap for gaining insights from BDA in the healthcare (patient care) domain. The researchers first define big data characteristics for healthcare and then examine BDA applications to healthcare in academic research, with a focus on NoSQL databases. In addition to that they discuss the limitations and problems of these applications, as well as the promise of NoSQL databases to address these issues and improve BDA healthcare research. The researchers then propose and present Med-BDA, a cutting-edge BDA architecture for the healthcare domain that addresses all current BDA issues and is built on the newest zeta big data paradigm. They also give effective tactics to secure Med-BDA's operation, as well as a summary of the primary benefits of BDA applications in healthcare. Awan et al. (2021) mentioned that the big data has transformed the world by creating enormous prospects for a wide range of applications. It contains a massive amount of data, particularly a plethora of data kinds that have proven to be quite useful in a variety of study disciplines. Researchers in the healthcare domain employ computational devices to extract enriched useful information from this data and create smart applications to tackle real-life problems in a timely manner. The existing literature is analyzed and appraised in this research work to discover deficiencies that affect the overall performance of accessible healthcare applications. It also intends to propose improved solutions to these gaps. The available literature presented from 2011 to 2021 is thoroughly examined in this complete systematic research work to determine the efforts made to assist doctors and practitioners in diagnosing diseases utilizing healthcare BDAs. A collection of research questions is developed to analyze the relevant articles in order to find essential aspects and optimal management methods, and these analyses are later used to create effective results. The findings of this systematic mapping suggest that, despite significant efforts in the domains of healthcare BDAs, newer hybrid machine learning-based systems and cloud computing-based models should be adopted to reduce treatment costs and simulation time, and achieve an improved quality of care. This thorough mapping will also improve doctors', practitioners', researchers', and policymakers' ability to use this study as evidence for future research. Koornneef et al. (2017) Researchers affirm that the government of the UAE intends to develop a world-class health system to improve healthcare quality and health outcomes for its population. To that end, it has made major healthcare changes during the last decade. The nature, scope, and success of these reforms have not lately been thoroughly examined. We review the progress and outcomes of health system reform in the UAE in this report. The researchers investigated relevant databases and other sources to discover published and unpublished studies, as well as other data, that were available between January 1, 2002, and March 31, 2016. Data from eligible studies were descriptively and narratively synthesized. (Waqas et al., 2021). The research confirmed that the Middle Eastern countries' growth and innovation in telemedicine have not been closely followed. As a result, the current study seeks to examine scholarly work done in the Arab world utilizing replicable statistical and Arfat, methodologies. A thorough search strategy comprised of terms relevant to the Arab region, EMRO countries, telehealth, medical diseases, and disorders were used to conduct an electronic search of the Web of Science (core database). A total of 1630 results were processed and indexed. The results showed that there is a lack of innovation in the field of digital health in Arab countries. In addition, there are many gaps in health research in Arab countries. Moreover, telemedicine research in Middle Eastern countries is still in its infancy.

Al Shamsi and Kais (2021) aimed to give a review of artificial intelligence, with a particular focus on the healthcare industry. The paper begins with a general introduction to global disruption, in which artificial intelligence has played a significant role, and then discusses the origins of artificial intelligence. Then, we create viewpoints on the existing and future impacts of artificial intelligence on the healthcare industry in general, and hospitals in particular. The study continues with a consideration of the strategic implications of these effects on hospitals and other healthcare stakeholders, with cases from the UAE used as examples.

Big data and healthcare are international experiences

Big data and healthcare in Estonia

The Estonian e-Health Foundation was established in 2005, bringing together representatives from major Estonian hospitals, the Estonian Emergency Medical Services Federation, the Estonian Association of Family Physicians and the Ministry of Social Affairs. Estonia has developed digital services in the areas of healthcare. E-Health services include digital prescriptions and digital patient records. The Estonian National Health Information System (EHIS) has been in operation since 2008 (Metsallik et al., 2018). The electronic database contains the health data of every Estonian from birth to death, the database provides access to medical data, prescriptions and medical images for each patient via the Internet in a safe and reliable way (Metsallik et al., 2018). The aim of the Estonian eHealth system is to develop patient-friendly, efficient and high-quality healthcare services. An EHIS system includes three main layers: the data layer, the data transmission layer, and the application layer. The data layer consists of data warehouses for storing medical documents and images. The Data Transport Layer provides a secure, Internet-based infrastructure for data exchange for both citizens and caregivers. The sophisticated application layer delivers health information to different parties (patients, healthcare providers, government agencies, policymakers, etc.) (Widén & Haseltine, 2015).

Big data and healthcare Germany

Patient-centeredness in medical research and care has become an important goal of German health policy. Healthcare in Germany aims to manage patient health by collecting important patient data from multiple sources linked to the patient's health information technology. In addition, each patient is divided into precise subgroups based on biological characteristics and lifestyle information. This approach relies on the use of large amounts of data, from genetic information and tissue biomarkers to information within healthcare centers. In this context, patients and hospitals constitute a stakeholder group.

Big data and healthcare in Japan

Japan has been leading the way in medical big data applications since 2009 by converting medical expenditure data into electronic form in hospitals and clinics. Since 2009, the government has stored electronic data records in its national database. Another type of big data that contributes to improving the quality and effectiveness of medical care is clinical data based on the Diagnosis Procedure Combination system (Hayashida et al., 2021). Diagnosis procedure combination (DPC) codes are 14 digits long. The code indicates, in addition to the name of the disease, the patient's age, weight, level of consciousness in digital form, surgeries and other treatments, drugs used, complications and their severity, which may affect the amount of medical resources required, or the injury for which most of the medical resources were spent during hospitalization Added to this are other relevant information, such as the number of days the patient spent in hospital and medical costs, which would make the data set more transparent for medical information. In contrast to medical expense data which are detailed lists of treatments, DPC data not only gives a comprehensive picture of the medical services that were provided but also clearly demonstrates the wide variation in treatment between different medical institutions for the same diagnosis (Tsuji, 2020). Japanese hospitals and clinics now have a wealth of big data characterized by what are known as the 3Vs: volume, speed, and variety. There are 1.34 million inpatients and 7.26 million outpatients daily across Japan, according to the 2011 Patient Survey prepared by the Ministry of Health, Labor, and Welfare. High mixing and low volume

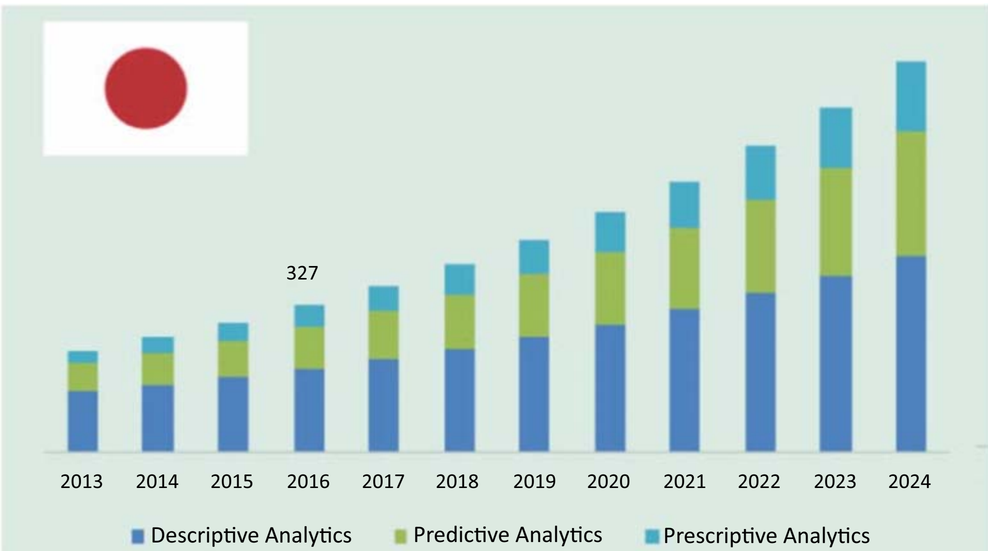

Figure 16.4 The healthcare analytics market in Japan during the period 2017–24.

production is the norm in clinic interfaces, where patients receive a wide variety of services precisely designed to respond to each individual's ailments. In addition, Japan has begun to use big data to deal with the elderly, as big data is used to obtain information about patients and the diseases they suffer from (Tsuji, 2017).

Current healthcare data can be found from many sources, such as the Medical Data Vision database, which contains more than 40 million patient records from more than 460 hospitals in Japan and is one of four Japanese datasets available in IQVIA's platform to analyze the data. When companies can access these data sets and compare them to other relevant data, they are able to quickly identify emerging healthcare trends, inform drug development decisions, and clearly define the journey of treatment. The Fig. 16.4 shows the healthcare analytics market in Japan during the period 2017–24.

The impact of big data on healthcare in the GCC countries

United Arab Emirates

The health sector is one of the emphasized sectors in UAE, hence the industry is seeing amazing growth. The healthcare industry is governed by both federal and state laws. The vision of the UAE is to provide world-class healthcare. with the technological advancements taking place in the UAE, big data provides a large database within the country, especially in the healthcare sector, which can help provide better health services. In addition, big data analysis helps improve health services and programs provided to patients. The UAE's healthcare system is supported by both government-funded healthcare services and a rapidly expanding private healthcare sector. The quality of healthcare given by both sectors is satisfactory. The UAE's healthcare business is recognizing the promise of big data analysis and has the potential to alter the healthcare system. The implementation of e-prescription and e-patient summary services is regarded as a critical step in providing safe and high-quality e-health services (Tinholt et al., 2013). The technology could assist pharmacists in reducing the number of errors caused by misreads, allowing them to devote more time to other vital issues, giving them an advantage over other pharmacists who do not practice prescribing. El Khatib et al. (2022) mentioned that as the amount of medical data in the EMRs system grows exponentially, so does the time necessary for health providers to read it. This means that physicians must increase the time allotted to each patient by the identical proportionality once more. Leyens et al. (2017) argue big data contributes to the improvement of the patient's health status, in addition to the possibility of predicting personal health and improving the doctor's decisions. The vision of the UAE is to provide healthcare at a high level, and the government seeks to promote innovation in the healthcare system to achieve the government's goal of providing high-level healthcare and ensuring sustainability in the provision of health services. The study

(Alhajaj & Moonesar, 2023) concluded that big data in the UAE can help monitor infectious diseases, early detection of disease, and track side effects of drugs, which can help make the right decision and help limit the spread of diseases. The USA HITECH Act assists in the adoption of EMRs, which contributes to the generation of data needed by various medical agencies and reduces health disparities.

The healthcare system in the UAE is operated by government-funded health services and the private health sector. The government's direction is to promote innovation in the healthcare system to achieve its vision of providing high-quality healthcare. Many strategies have been followed to ensure that people have access to a high-quality and sustainable care system. The healthcare sector in the UAE depends on analyzing big data in a way that serves the healthcare system (see Fig. 16.5). The UAE has introduced a unified insurance coding system. The availability of big data will enable insurance companies to draw a clear picture of healthcare in the region. It will allow them to accurately predict the validity of claims (Sarabdeen & Moonesar, 2018). In 2017, the Dubai Health Authority (DHA) launched the "Salama" computerized medical records system. With the implementation of this system, patients will have access to centralized patient records. The system integrates 25 apps via a single interface. Patients' appointments, queue management, radiography, pharmacy, laboratory information system, and dentistry records are all available with a single click (Khaleej Times, 2017).

Dubai endorsed Health Data Protection Regulation No. 7 of 2008 as a supplementary data privacy regulation to safeguard health data protection. The legislation only applies to institutions regulated by the Dubai Healthcare City Authority and does not apply to all healthcare facilities and providers in Dubai. The authority considered

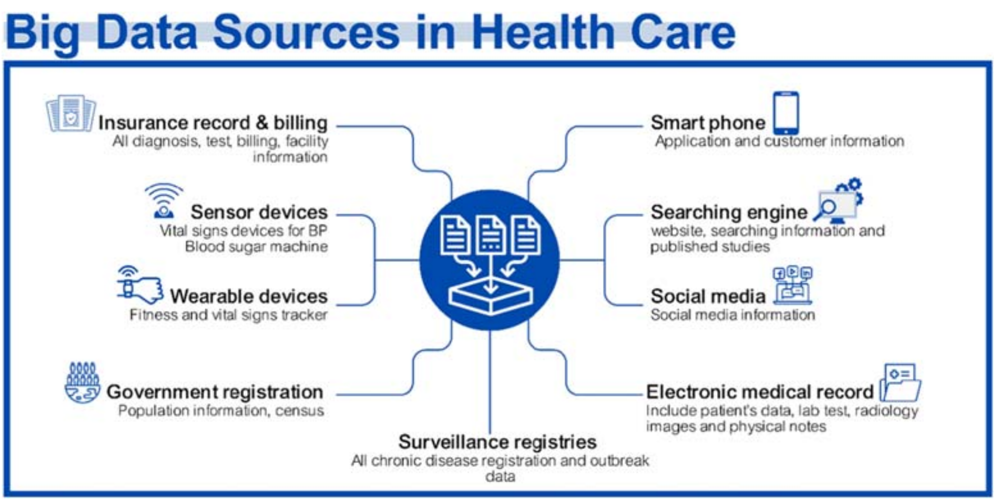

Figure 16.5 The healthcare analytics market in Japan during the period 2017–24. *From Alhajaj and Moonesar (2023).*

provisions in the Organization for Economic Cooperation and Development (OECD) Guidelines on the Protection of Privacy and Transborder Flows of Personal Data; European Parliament Directives on the Protection of Personal Data; Asia-Pacific Economic Cooperation (APEC) Privacy Framework; and Health Insurance Portability and Accountability Act (HIPPA) Privacy when developing the regulation.

Sultanate of Oman

The health system in the Sultanate of Oman is characterized by its comprehensive coverage for both citizens and noncitizens. Total health spending is approximately 2.5% of GDP. The health system receives its funding directly from the government. The Sultanate of Oman has made remarkable achievements in the field of developing the health situation over the past four decades. Healthcare data in the Sultanate of Oman are collected from various sources, which are electronic records of patients, medical imaging, the Al-Shifa + 3 program, and disease diagnosis, which constitute a comprehensive medical file for each patient since birth. The role of EHRs is to document a patient's health information from birth to death. The EHR system is a digital product that enables users (doctors, researchers, administrators, etc.) to access the stored data. Al-Muzahmiyah (2021) concluded that the shift to electronic records and big data contributed to simplifying work procedures, reducing errors, facilitating access to information, and preserving patient privacy. In addition, big data is of great importance to the patient, represented in reaching the appropriate medical diagnosis. The data provides additional information and links related to the patient's health and contributes to disease prevention. The Al-Shifa program, it includes more than 35 forms that contribute to providing information about the patient, including medical records, doctor's system, pharmacy system, X-ray system, etc. (Al-Muzahmiyah, 2021). Due to the development of data systems, it has become easy to analyze each patient's data with high accuracy, which contributes to saving many disease cases.

Kingdom of Saudi Arabia

Saudi Arabia has witnessed rapid social and economic changes, which have contributed to major developments in the public healthcare system and widespread health reform. In Saudi, every year, 1 billion patient visits are recorded in their hospital EHR systems. In addition, information about medical disorders, drugs, and treatment approaches is being expanded. Thus, a health information system is required to organize, interpret, and recognize patterns in these data. As part of Saudi Vision 2030, in 2015 the Kingdom launched the National Transformation Program. It is an executive program designed to transform healthcare into an electronic system (Al-Kahtani et al., 2022). The e-healthcare system is easily implemented in many medical facilities, and wireless body sensor networks based on home care applications are remotely used to monitor and treat patients. Other medical services are also provided to the patient based on the data transmitted by him to the medical practitioner. According to the World Health Organization, "the Saudi healthcare system contains hospitals that surpass many world-class hospitals" (Alharbi, 2018). Al-Kahtani et al. (2022) study concluded that there are rates toward the implementation of digital transformation in healthcare facilities in the Kingdom of Saudi Arabia, and this led to an increase in the amount of data available on patients. Saudi Arabia has made great strides toward digitizing its health system and has implemented many improvements in patient experiences, quality and efficiency of care. The Kingdom has already taken several steps in this direction, starting with the implementation of the healthcare sector transformation program within the framework of Saudi Vision 2030 in 2016, with the aim of improving the efficiency and quality of healthcare. Initially, eHealth Services efforts focused on digitizing solution provider data, innovations in EHRs, and implementation of clinical workflow management systems. Since the outbreak of the COVID-19 pandemic, the Kingdom has expanded the application of its digital solutions, including consumer-centric solutions, such as virtual care. Digital technology provides healthcare systems with many benefits, including coordinated care services, real-time monitoring of chronic diseases Accurate diagnoses of disease conditions, more efficient and effective treatments, and a comfortable and beneficial experience for both the patient and the doctor. Digital healthcare brings significant economic benefits, including cost savings, that can be reinvested in other priority areas of health. Healthcare innovations are expected to provide economic benefits of more than $15 billion to $27 billion for the health system as a whole in 2030; This includes the Ministry of Health, service providers, fee payers, doctors and patients. Given the importance of big data in supporting society, the "National Transformation Program 2020" was established, one of the executive programs for the Kingdom of Saudi Arabia's Vision 2030, which worked to identify the challenges faced by government agencies. As a result of this transformation, the Ministry of Health seeks to raise the quality and efficiency of health services. Among the achievements made by the health sector as a result of the use of big data in healthcare are the recruitment of Saudi health personnel, raising life expectancy, and reducing infant mortality.

Kuwait

Kuwait has made tremendous strides in adopting digital health solutions, through the use of a telehealth system, EHRs, laboratory information, imaging systems, radiological information, and health information exchange. Regarding telehealth, Kuwait has benefited from shared experiences with global organizations, such as the World Health Organization and the Telemedicine Society of India. Healthcare organizations are keen to take advantage of information and communication technology to digitize their systems and processes in order to achieve growth and expansion, in addition to improving efficiency and health outcomes. Electronic healthcare records are central to digital transformation. Since 2016, many private hospitals in Kuwait have started implementing EHR systems to provide information on medical conditions and treatments for each case. Kuwait has also invested in telehealth to expand access to digital health solutions. on digitizing medical records, implementing electronic prescriptions, and developing a national system for exchanging medical information via mobile phones, in addition to providing health information for remote treatment (Kuwait Digital Health Market Analysis). During the Corona pandemic, the National Center for Big Data was established, where huge health data is collected, entered, analyzed and linked, in addition to developing related systems, programs and applications. This is done by creating an open data platform used by (doctors, patients, researchers, etc.).

Qatar

Statistics show that every hospital in Qatar produces on average about 665 terabytes of data annually, but 80% of this data is not processed and needs to be restructured to benefit from it. Qatar National Vision 2030 ensures a great focus on e-health by making use of the data provided by the health system. E-health is not an end in itself, but rather a supportive technological fabric that will help and accelerate the achievement of the national health goals set by the National Health Strategy. Focusing on data quality is fundamental to the success of the eHealth system. The e-health system helps to make important decisions regarding patient safety by trusting the basic data received from multiple sources to ensure maximum benefit from the health system, and at the same time reduce errors that may result when data is incomplete or from unreliable sources (Qoronfleh et al., 2020). The availability of Genomic information to numerous patients on the service provider network or cloud. The best medicine and therapeutic regimen for a patient are chosen using genomic information. Individualized healthcare will result from the utilization of genetic information, and health maintenance will include predictive and diagnostic genetic testing.

However, concerns have been raised about the proper gathering, storage, and use of personally identifiable genetic information in genetic testing and pharmacogenetics. The gathering and use of genetic data concerns not only the privacy of very sensitive data of individuals, but also their relatives who may share the same genetic information. The Genetic testing not only provides information about past, present, and future health or disease problems, but it can also predict future health or illness issues. Because a person's genotype is almost unique and constant, there is a great need for such information (Claerhout and DeMoor, 2005; Hassol et al., 2004).

Bahrain

Healthcare in the Kingdom of Bahrain is provided to the Kingdom's residents regardless of their nationality. The Supreme Council of Health is the authority responsible for the healthcare sector. The Ministry of Health has an indirect relationship with the National Health Regulatory Authority, Hikma Pharmaceuticals, and public health, environmental and social agencies. The two main stakeholders that need access to medical data are providers and buyers. The Ministry of Health in Bahrain seeks to provide high-quality health services, by moving to the application of modern technologies in the health sector. The first step in digital transformation in the healthcare sector was the launch of the National Health Information System. The system connects healthcare institutions, allowing access to any patient's data at any time and from anywhere. Therefore, modern technologies have contributed such as IoT, big data, and remote patient monitoring systems to help reduce patient movement. In addition, digital transformation has brought about a major change in the healthcare system, through the conversion to EHRs.

Conclusion

Technology has become a vital part of our daily lives. The adoption of new technologies has drastically changed our daily lives. Big data provides an opportunity to exchange information with different parties. Attempts to benefit from BDAs have become a common factor among various companies, universities and research centers that can also benefit from big data. In healthcare, big data can be used as a data collection and analysis system, where data is collected from various sources. The use of big data makes it possible to monitor the health status of patients, by recording all patient data and transmitting it via the Internet. Big data, combined with the IoT, has revolutionized the way we can track patient health data. Big data can make a quantum leap in the world of medicine, by providing complete information about the patient, reducing costs, in addition, it can help in making predictive analyses that can be used to treat the condition of each patient separately. In most countries of the world, medical service providers have shifted from the traditional paper-based medical fleet to the EMR. EMRs are a rich platform containing complete patient information.

In general, big data can be divided into three forms: structured, unstructured, and semistructured. Structured data is stored and processed in a specific format. It is data that can be easily retrieved and read. As for unstructured data, it faces multiple challenges in terms of processing as well as extracting useful information from it (Wu & Lin, 2018). In the healthcare sector, we need to analyze unstructured and semistructured data to benefit from it in providing patient information.

On the other hand, the extraction and processing of big data can be subject to social and legal challenges (Mittelstadt & Floridi, 2016). The development of big data has led to the emergence of many challenges and problems including constant changes in healthcare data, resulting in huge amounts of data being stored and processed. In addition, health information is not centralized due to the unstructured and semistructured data that is kept, moreover, traditional database systems cannot be used to process and store data due to its huge size. One of the problems facing big data in the Arab Gulf countries is that EMRs are not centralized. Each healthcare provider has its own medical records system. In addition, there is no unified government approach and policy regarding big data mining or storage. These challenges can be overcome by using advanced solutions to analyze that data. Therefore, healthcare providers need to be equipped with the right infrastructure to systematically process and analyze big data. The cloud computing model is one health information technology infrastructure that facilitates the sharing of EHRs.

The limitations of this research are represented in an attempt to highlight the impact of big data on medical institutions and healthcare in the GCC, by examining the previous literature related to the subject. Therefore, we recommend conducting future studies that use other research tools such as personal interviews, questionnaires, and applied studies on big data in the Gulf countries, as well as conducting studies on expected auditing services for institutions that apply big data, in addition to examining the risks resulting from the use of big data in health institutions. Finally, we recommend conducting a study on the impact of big data on medical institutions in different countries around the world.

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CHAPTER 17

Artificial intelligence and the delivery of patient-centered care in the Gulf region: navigating the ethical landscape

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Introduction

Overview of artificial intelligence technologies in healthcare

The global healthcare landscape is undergoing a significant transformation with the widespread integration of artificial intelligence (AI) and machine learning (ML) tools. The healthcare sector, has emerged as a prime candidate for the application of these advanced technologies. Due to substantial investments and their promise within this sector, AI technologies are gaining rapid traction (Sun & Medaglia, 2019). Among the initial applications of AI in healthcare in the 1980s was pattern recognition-based computer-assisted detection for diseases in images (Lee et al., 2019). This development marked the beginning of a series of similar innovations. Significantly, the Food Drug Administration's (FDA) increasing approval rate for AI and ML tools is evident, reaching 521 by mid-2020 (Matzkin, 2021). Fig. 17.1. This trend has corresponded with a substantial increase in activity aimed at healthcare-related AI and ML tools. Such technologies can be applied to disease diagnosis and detection, personalized treatment strategies, drug discovery and manufacturing, clinical trial research, radiology and radiotherapy, smart electronic health records, and even epidemic outbreak forecasting (Lamberti et al., 2019). It is worth mentioning that most of the approved AI tools are in image-based specialties such as radiology, pathology and dermatology.

These progressions are anticipated to confer multiple advantages within healthcare delivery such as early disease detection, enhanced medical image analysis, increased personalized care and more efficient resource allocation. See Table 17.1

Digital Healthcare in Asia and Gulf Region for Healthy Aging and More Inclusive Societies
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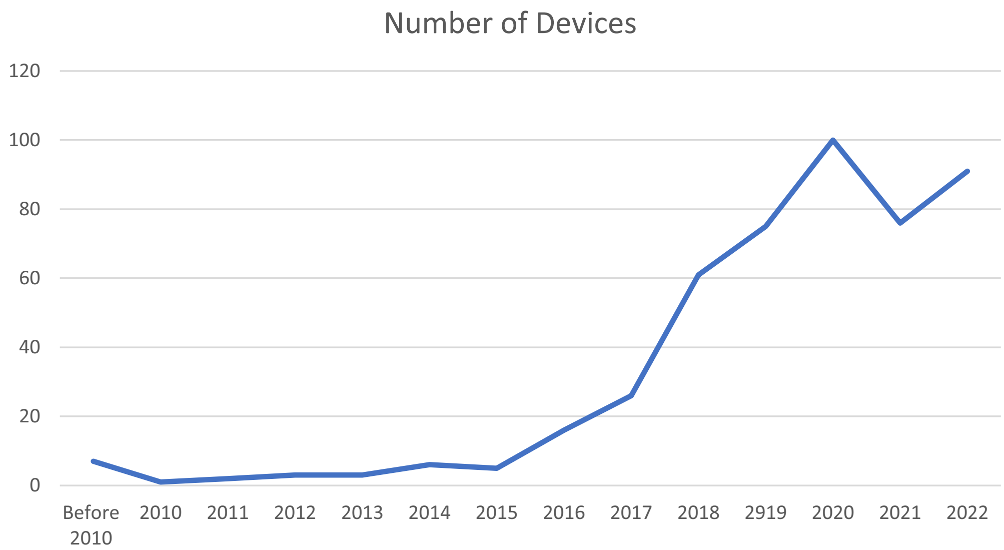

Figure 17.1 The number of Food Drug Administration-approved artificial intelligence/machine learning-enabled medical devices per year

On the contrary, there are several concerns regarding the use AI in healthcare. Some of these concerns relate to algorithm bias, data privacy, system transparency and accountability. See Table 17.2.

One of the healthcare areas that warrant particular attention and consideration is the impact of AI applications on the patient—doctor relationship and whether it will strengthen or weaken patient-centricity in healthcare. This chapter discusses the advantages and potential drawbacks of harnessing these technologies in healthcare, with a focus on the patient—doctor relationship in the context of the Gulf Cooperation Council (GCC) countries.

Healthcare systems in the Gulf Cooperation Council countries

The Healthcare system in the Gulf Cooperation Council countries

Over the past 30 years, the GCC nations have made significant investments in health infrastructure, including the establishment of medical schools, universities, and hospitals (Ram, 2014). During the period spanning from 2010 to 2020, the GCC region led in healthcare infrastructure investments, resulting in a twofold rise in the number of hospitals, primarily propelled by government-driven initiatives. The predominant trend in new construction primarily involved the establishment of sizable hospitals, often referred to as medical cities. The emphasis has been on enhancing services

Table 17.1 Potential benefits of artificial intelligence applications in healthcare.

Potential benefit of AI in healthcare	Example	References
Early disease detection	Utilizing AI-driven methods like machine learning and deep learning models for the early diagnosis of various diseases such as skin, liver, heart, Alzheimer's, and more.	Kumar et al. (2023)
Medical image analysis	Google's DeepMind AI can analyze medical images, such as X-rays and MRIs, to detect abnormalities like diabetic retinopathy or lung cancer, enabling faster and more accurate diagnoses.	Pandya et al. (2018)
Personalized treatment plans	PathAI uses ML to help pathologists identify and classify diseases, leading to personalized treatment plans based on a patient's unique pathology.	Vipul Baxi et al. (2021)
Drug discovery and development	Atomwise's AI platform accelerates drug discovery by simulating the interactions between molecules, enabling the identification of potential drug candidates more efficiently.	Rashid (2021)
Administrative efficiency	Chatbots like Ada Health assist with patient inquiries, appointment scheduling, and administrative tasks, reducing the administrative burden on healthcare staff.	Bates (2019)
Telemedicine and remote monitoring	HealthSuite platform uses AI for remote monitoring of patients, enabling healthcare providers to track vital signs and offer timely interventions for chronic conditions.	Philip et al. (2021)
Virtual health assistants	Buoy Health's virtual assistant helps patients self-diagnose and understand their symptoms, offering guidance on when to seek medical attention, improving healthcare accessibility.	Hwang et al. (2020)
Workflow optimization	Cerner's AI-powered solutions optimize hospital workflows, improving resource allocation, reducing wait times, and enhancing patient care quality	https://www.cerner.com/solutions/intelligence, no date; Li et al. (2022)

through the addition of departments dedicated to oncology, stroke care, and neonatal services (Frost & Sullivan, 2020).

In most GCC countries, the healthcare system grants citizens unrestricted access to government-provided medical services (Almoajel, 2012; Alkhaibari et al., 2023). Private hospitals are increasing in number in the GCC due to the increased demand and they

Table 17.2 Concerns associated with the use of artificial intelligence in healthcare.

Concern of AI application in healthcare	Example	References
Data privacy and security	Patient records and medical data can be vulnerable to breaches due to software vulnerabilities, security failures, or human errors	Seh et al. (2020)
Bias and fairness	AI algorithms may exhibit bias in diagnosis or treatment recommendations depending on the data used for training and testing	Parikh et al. (2019)
Lack of transparency	The "black-box" nature of some AI models can make it challenging to understand how they reach decisions, making it difficult to trust and validate their recommendations	Wang et al. (2020)
Liability and accountability	Determining liability in cases of AI-related medical errors can be complex, raising questions about who is responsible when an AI system makes a diagnosis or treatment recommendation that leads to harm	Smith (2021)
Cost and accessibility	The initial cost of implementing AI systems in healthcare settings can be substantial, potentially limiting access to advanced healthcare services in lower-income or underserved communities	Nordling (2019)
Clinical decision support limits	Overreliance on AI for clinical decisions may lead to concerns about clinicians becoming too dependent on AI recommendations and potentially missing critical nuances in patient care	Gaube et al. (2021)

are regulated by governmental policies and guidelines. Over the past decade, there has been a 20% to 30% increase in private sector investments within the healthcare sector, with a substantial 90% of these investments directed towards the development of hospital infrastructure. It is worth highlighting here that the healthcare system is structured into three tiers: tertiary, secondary, and primary healthcare, which enables patients to receive appropriate care based on their clinical condition (Frost & Sullivan, 2020).

Collectively, these efforts and investments have led to a noticeable enhancement in the quality of healthcare services offered. In fact three of the GCC countries namely Oman, UAE and Saudi Arabia ranked among the top 30 best-performing healthcare systems among 191 countries in the WHO 2000 ranking (Tandon et al., 2008). It is worth mentioning that the ranking used 5 main indicators which are population health, health inequality, health system responsiveness to population needs, distribution of this responsiveness, and fairness in financing (Tandon et al., 2008). The improvements in healthcare have contributed to extended life expectancies and substantial population growth, positioning the GCC countries as one of the world's rapidly expanding populations (Khoja et al., 2017), particularly among those aged 60 and above (Chikhaoui, Alajmi, & Larabi-Marie-sainte, 2022). According to the ISI World Statistics Congress, the population has nearly doubled over the past two decades, increasing from 26 million in 1995 to 56 million in 2021. Furthermore, there is a substantial influx of expatriates in GCC countries, constituting approximately half of the total population (https://www.lexology.com/library/detail.aspx?g = 7d6b9f32−422a-4ff4-ae72−96ebff2e7acb, no date).

Challenges facing the healthcare system in Gulf Cooperation Council

The healthcare system in the GCC countries is grappling with significant shifts in demographics and disease epidemiology. Key demographic changes, including rapid population growth, an aging population, and an influx of expatriates, are stretching the healthcare system and exposing gaps in services whilst also contributing to increased healthcare costs. For example, there seem to be gaps in specialized rehabilitation and long-term care facilities in the region to cater to the need for cardiac rehab and stroke care. Additionally, the sedentary lifestyle introduced as a consequence of recent regional industrialization has elevated the risk of lifestyle-related factors contributing to noncommunicable diseases (NCDs), leading to premature deaths and associated complications (Chigom, 2018; Fadhil et al., 2022). The GCC countries rank among the highest globally in terms of lifestyle-related risk factors (https://diabetesatlas.org/, no date) and the resulting mortality (Moradi-Lakeh et al., 2017), including conditions such as diabetes, cardiovascular issues, and obesity. However, the current healthcare systems in these nations might not be sufficiently equipped to effectively tackle this growing burden.

Furthermore, the inadequate development of the primary care system, which is regarded as the cornerstone of modern healthcare delivery is another challenge. This deficiency has resulted in limited access to healthcare, delayed diagnoses, and suboptimal management. As a result, a significant number of patients are being referred to hospitals, leading to the overuse of hospital services. This situation could be mitigated by investing in primary care services to enable early diagnosis and the ongoing management of treatment at the primary healthcare level.

The situation is exacerbated by a scarcity of adequately trained healthcare professionals in the region, which strains the system and leads to deficiencies in healthcare delivery (Fadhil et al., 2022). According to the most recent report from *Alpen Capital*, collectively these challenges are expected to increase the GCC healthcare spending up to US$135.5 billion by 2027 (https://alpencapital.com/research/2023/gcc-healthcare-report-mar20.pdf, no date) compared to US$18 million in 2008 (Khoja et al., 2017). Moreover, the pressures on the healthcare system have led to a scarcity of time available for patient−doctor interactions, resulting in a shift towards a resource-centric or staff-centric approach instead of person-centered care (Chandra, Mohammadnezhad, & Ward, 2018). Presently, the time allocated for doctors is frequently inadequate for proper communication and empathetic relationships where patients are often perceived as passive recipients of care, with limited involvement in healthcare decisions and planning.

Tackling the challenges

The GCC countries have noticed these challenges and several strategic initiatives have been undertaken to address them (Khoja, 2009; Al-Duwairi, 2015). First of all, the GCC countries used to allocate approximately 2%–4% of their GDP to healthcare, in contrast to the United States, which spends 17%–18% of its GDP on healthcare. The global average expenditure as a percentage of GDP stands at 9.88%. Therefore, the GCC countries aim to increase the GDP contribution to healthcare for the next national health vision (Frost & Sullivan, 2020). Furthermore, these countries have implemented various measures to reduce costs and enhance services, including the introduction of mandatory health insurance, the establishment of public–private partnership models for healthcare, and the adoption of advanced digital technologies to combat these challenges (Chikhaoui et al., 2022) such as AI and ML. The healthcare visions of the GCC countries include transformational goals to improve health and quality of life, to ensure safety in delivered care, is effective, patient-centered, and timely and to improve the value of care by containing costs and improving outcomes. Indeed the implementation and strengthening of a patient-centered healthcare model is core to the transformation of care delivery in the region (Khoja et al., 2017). It becomes evident that GCC countries have structured their national health strategies around the nine targets delineated within United Nations Sustainable Development Goal number 3 (SDG 3), titled "Good Health and Well-Being" (Azar & Raouf, 2017). These targets encompass nine endeavors such as reducing morbidity and mortality rates within vulnerable demographics, including mothers, newborns, the elderly, and children. Moreover, they involve efforts to tackle the prevalence of both communicable and NCDs, mitigate risk factors like tobacco use, substance abuse, road traffic incidents, hazardous chemicals, and pollution, ensure universal healthcare access, and reinforce the overall healthcare sector (Dagron, 2022).

Examining AI as a catalyst and accelerator for attaining the SDGs presents complexity due to the interconnectedness of various SDGs (Goralski & Tan, 2020; Vinuesa et al., 2020; Singh et al., 2023). For instance, if we consider an AI tool designed to enhance the well-being and health of women, aligning with SDG 3, it necessitates the concurrent deployment of other tools to fulfill SDG 4, aimed at improving access to education, and SDG 5, which focuses on achieving gender equality (Waage et al., 2015).

Attention to artificial intelligence in the Gulf Cooperation Council countries

There is significant optimism regarding the capabilities of AI and ML tools to enhance various facets of existing healthcare systems and address prevailing challenges, with the ultimate goal of enhancing patient care, outcomes, time efficiency, and overall patient satisfaction. Experts have emphasized AI's potential to "give the gift of time" fostering improved patient experiences and strengthening doctor—patient interactions (No date a). However, a pertinent query arises: How will this additional time be allocated to benefit patients?

Due to promises of AI and ML and the considerable investments made by the GCC countries in healthcare systems and infrastructure, the region is considered a fertile ground for the implementation of such tools. Recent statistics highlight a pronounced surge in attention and investment towards advanced technology and AI applications, particularly within the healthcare sector in Gulf countries (Hanafi et al., 2021). The COVID-19 pandemic expedited the integration of digital health technologies, underscoring the potency of innovation in responding to crises (Tan & Ong, 2002).

Integration of AI has become an inherent aspect of the strategic planning and national visions of GCC governments (Hanafi et al., 2021). Reports show that the economic contribution of AI in the GCC countries is expected to exceed US$277 billion by 2030 (Saudi Gazette, 2019; Hanafi et al., 2021). Notably, approximately two-thirds, of the 96 strategic objectives outlined in Saudi Arabia's Vision 2030 are intricately linked to data and AI. Additionally, Oman's proactive initiative in establishing the National Program for Artificial Intelligence and Advanced Technologies underscores its commitment to fostering AI adoption and crafting relevant policies (Executive Program for Artificial Intelligence & Advanced Technologies, no date). Furthermore, the UAE stands as a pioneer by dedicating an entire ministry to AI (Waqas et al., 2021). UAE has also launched an integrated EHRs to facilitate seamless connectivity among public hospitals and clinics. Qatar and Saudi Arabia have taken a proactive step towards enhancing healthcare services through the introduction of an e-health program and digitizing medical records. Furthermore, Oman's Ministry of Health has advanced e-health services by linking identity cards with hospital registration (Khoja et al., 2017). Several applications have already been integrated into the healthcare systems of GCC countries. For instance, the Director of the Center of Healthcare Intelligence at King Faisal Specialist Hospital & Research Center highlighted the utilization of virtual reality technology to support children with autism in acquiring crucial life skills (No date b). Moreover, the recent implementation of a tele-ICU platform for remote critical care and the development of a remote monitoring system for patients with chronic conditions aims at facilitating care access while minimizing infection risk (No date b). A recent Oxford Insight report which measures a government's readiness to apply AI to improve public services has shown that five of the GCC countries namely Saudi Arabia, UAE, Qatar, Oman, and Kuwait ranked among the top 50 economies in the world in AI readiness. According to this report, the UAE and Saudi Arabia both have strong digital government infrastructure and high scores in the Digital Capacity dimension (Shearer et al., 2022).

Focusing on the healthcare system, the region has noticed a substantial upsurge in a number of publications focusing on the use of AI within the healthcare systems. A noticeable increase in the number of conferences and symposia dedicated to this topic has also been observed. Intriguingly, studies evaluating the viewpoints of physicians, medical students, and patients regarding the incorporation of AI and ML in healthcare have generally displayed a positive perception (Karches, 2018; Ahmad et al., 2023; Alanazi et al., 2023; AlZaabi et al., 2023). Interestingly, more than half of the respondents from Saudi, Qatar, and UAE to a survey voiced an acceptance of robots and AI tools replacing doctors (Hanafi et al., 2021). This startling finding might be explained by the demographics of the GCC where approximately 70% of the GCC population are younger than 30 years of age. Generally, this age group is more receptive and at ease with AI-based solutions.

Artificial intelligence tools and the patient—doctor relationship

As touched on above there are many different ways in which AI tools can be integrated into routine healthcare delivery. There is potential for enhancing the way in which we deliver healthcare by improving patient outcomes and reducing provider burden is high. At the same time there is concern that, just like claims made about the implementation of the electronic health record, AI's promise will not match up with its functional reality. Rather, structural problems within contemporary biomedicine will drown out any possible benefits. For example, commentators have noted that the AI tools are more likely to be implemented within "rich" healthcare systems and trusted by technologically-savvy patients and providers, and thus more likely to service socio-economically advantaged populations; the minority and marginalized would lose out on the benefits of AI in healthcare. While this and other societal-level concerns about how AI is deployed within healthcare are extremely important to address, this chapter will use the lens of the patient—doctor relationship to analyze the potential benefits and harms that integration of AI may engender. Before advancing further, the reader will benefit from a discussion of the patient—doctor relationship.

Critical aspects of the patient—doctor relationship

Since ancient times, healers and those seeking their assistance have been connected through a sacred bond where one party exposes their vulnerability to the other in the hopes that the other's specialist knowledge will bring relief. The privileges of being a healer came together with ethical duties, which were later on spelled out within oaths and codes of practice. As the healer's art professionalized into modern healthcare, notions of fiduciary responsibilities were attached to the role and explicated in ethics manuals and practice guidelines. Thus at the core of contemporary medicine is the dyad of a patient and a doctor.[1] It is in the context of this relationship that ethical duties are discharged and moral decisions are made. In their landmark article, Emanuel and Emanuel, describe four models for the physician—patient relationship; the paternalistic, the informative, the interpretive, and the deliberative. Each of these models sets out the role, and thus the ethical obligations of, the physician differently.

In the paternalistic model, the physician is conceptualized as the patient's guardian whereby they must promote the patient's well-being in all circumstances. The physician uses their knowledge and skills to diagnose and treat the patient. After soliciting information about what the patient's objective notions of health and well-being are, the physician presents the patient with selected information that will encourage the patient to consent to an intervention that the physician considers to best meet those goals. The ethics of guardianship work out such that the physicians must place the patient's interests above their own and protect them from making incorrect choices.

The informative model views the physician as a technician where the patient is provided with maximal information about their malady and its possible solutions. The patient is then asked to select the course of action that the physician will execute. As technical experts, physicians have important obligations to provide truthful information, maintain competence in their area of expertise, and be subservient to the patient's selected course of interventions. In between these two extremes are the interpretive and deliberative models.

In the interpretive model, the physician is conceived of as a knowledgeable counselor who both explains the medical considerations and also elucidates and interprets patient values surrounding courses of treatment and personal health and well-being. Importantly, the physician does not dictate to the patient; he or she helps the patient to understand their own values and apply them to the medical situation at hand. In addition to those enumerated in the informative model physician's obligations also include engaging in nondirective consultation.

The deliberative model adds to this obligation and envisions the patient—doctor encounter as a persuasive consultation where the patient's, and at times even the physician's values, surrounding the course of treatment are explicated, discussed, and navigated. In this model, the physician is conceptualized as a teacher who empowers patients along the journey to self-discovery by weighing moral choices around medical interventions. The ethical responsibilities of physicians include, in addition to those in the informative and interpretative model, not coercive.

[1] This chapter focuses on the patient-doctor relationship for rhetorical and practical purposes. Yet we acknowledge that the more expansive term of a healthcare provider could have been used for there are nonphysicians who deliver critical aspects of healthcare and the ethical ramification of using AI tools apply to those professionals as well.

Among the models, the authors prefer the deliberative model because it advantages a robust notion of patient autonomy which requires individuals to critically assess their own values and preferences, and humanizes the physician as a caring being with the capacity to reason, persuade, and be prudent and exercise restraint (Emanuel & Emanuel, 1992).

In addition to these models, the concept of accommodation needs to be added. First elucidated by Siegler, physician—patient accommodation refers to the ongoing process by which patients and physicians decide to enter into a relationship and engage with one another through the course of therapy. Both patient and physician values are explicated and considered (in other words accommodated) as the relationship proceeds. According to Siegler, it is the process of accommodation that grounds moral and ethical duties in healthcare and allows for true shared decision-making (Siegler, 1982).

The patient—doctor relationship and patient centricity in the healthcare

In medieval times, circa the ninth century, a famous Arab physician, Ishaq bin Ali al-Ruhawi published a landmark treatise entitled "The Practical Ethics of the Physician" which was one of the first manuscripts to deal with the relationship between patient and doctor, and to detail how the physician must comport himself in order to become the most ethical and virtuous, and thus best, physician (Martin, 1967). Many commentators see this work as seminal in how Arab and Muslim norms align with modern conceptions of patient-centered care (PCC) (Al-Ghazal, 2004; Webair, 2020). Today, person-centered care is considered to be the gold standard as it is shown to improve patient satisfaction with healthcare as well as healthcare outcomes.

This influence is reinforced by Islamic cultural norms and beliefs that profoundly influence patient attitudes, and health-related practices (Matusitz & Spear, 2015). In the context of GCC, the application of PCC builds upon strong family networks and social support where the patients, the family and the community are involved in the health decision-making (Fakhr El-Islam, 2017).

Yet, in reality, the current healthcare system in the GCC is challenged by demographics and epidemiologic factors that have negatively affected the patient—doctor relationship and patient-centricity. Clinics have become more congested and the interaction between doctors and patients has become constrained due to capacity and time limits, resulting in reduced and possibly poorer patient—doctor communication. Consequently, continuity of care and patient trust has suffered (Chamsi-Pasha & Albar, 2016). In a recent study in Saudi Arabia, patients' expressed an understanding of overwhelming physician schedules but desired good communication with their physicians and continuity of care (AlFaris et al., 2023). Furthermore, the strain in the healthcare system has yielded a shift of care to a resource-centric or staff-centric approach instead of person-centered care (Al-Sahli et al., 2021).

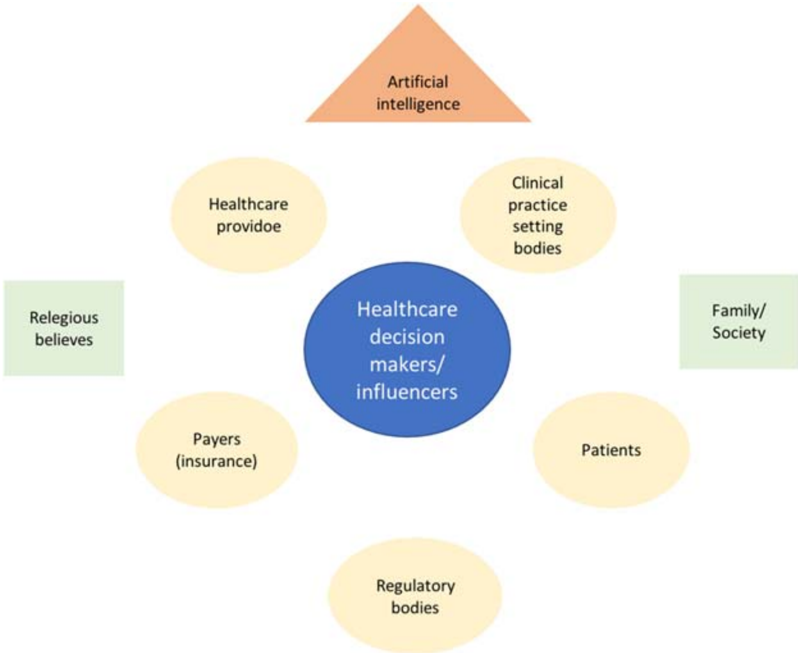

Figure 17.2 Healthcare decision influencers. *Oval*: Standard model of Clinical Decision influencers. *Square*: Extra decision influencers in the context of GCC due to strong family and religious influence on patient's decision. *Triangle*: AI is a new decision influencer where it contributes to a decision according to patient's data.

Does AI hold any promise to improve this situation? Some argue that the use of AI in healthcare will further exacerbate the gap in patient centricity and might introduce a new form of paternalistic care where AI is in charge of decision-making with no human influence (Jotterand & Bosco, 2020). See Fig. 17.2. One pressing ambiguity, is how AI algorithms can maintain patient's autonomy and preferences regarding management plans; are they capable of factoring in social, cultural and biological dimensions of patient decision-making? (Jotterand & Bosco, 2020; Sparrow & Hatherley, 2020).

As we analyze the possibilities for AI in healthcare, we will consider how they may implicate the ethical duties that surround the patient—doctor relationship models.

Potentials for enhancing the patient—doctor relationship

The possible applications of AI in healthcare are diverse and the posited benefits of incorporating AI tools within healthcare are many. Moving beyond the possible to the practical, there have been many different on-the-ground implementation tests of AI in a myriad of healthcare contexts, some of which have been noted above. Herein we comment on three principal ways in which AI has been/is being integrated into healthcare delivery and the potential enhancements such integration offers.

The use of advanced AI and ML algorithms to *aggregate and analyze healthcare data in order to assist with the diagnosis, prognostication, and treatment of diseases* is widely heralded as a boon. Vast amounts of information can be efficiently gathered and summarized by AI tools, and ML-based prediction algorithms enable these tools to function as adjuncts to physician decision-making. Illustratively, multiple studies compare the accuracy of AI tools with that of physicians in radiographic-based diagnosis and demonstrate equivocal results with AI perhaps being less time and human-capital intensive (Topol, 2019). On the other hand, Watson, IBM's supercomputer, was an epic failure in outperforming oncologists when recommending cancer treatment regimens for patients (Ross & Swetlitz, 2017). There are clear shortcomings in such predictive algorithms that may reproduce biases based on limited datasets, fail to account for patient-centered outcomes due to lack of data capture, and the like (Gerke et al., 2020). However, technologies are being ever-tweaked to become more efficient and efficacious in performing what would have traditionally been a physician's role.

Most commentators hold that these tools must be adjunctive and not supplant the physician for it is the physician and not the maker of the AI tool that has a fiduciary responsibility towards the patient; the AI tool is not a moral actor. However interesting moral questions arise; Is the physician morally obligated to act upon the AI's diagnostic analyses and/or treatment recommendations when they are known to produce superior results, for example, mortality benefits for the patient? Is informed decision-making compromised and hence respect for patient autonomy threatened when AI recommendations are based on unexplainable black-box algorithms?

With respect to the patient—doctor relationship, the potential enhancing aspect of this AI role is in its ability to furnish accurate information to support decision-making. Data is foundational to deliberative, interpretative, and informative models of the patient—doctor relationship within which the dyad considers how various treatment courses align with held values and patient preferences. Should AI tools quickly furnish accurate data that projects the benefits and harms of various treatment courses with respect to patient goals then the patient and doctor can spend more time discussing these options and thus make more informed decisions.

Another area where AI-based tools are rapidly being incorporated into medical practice is in *patient communication*. For example, chatbots are used to facilitate medical triage based on patient input and symptom reporting, and to check in with and provide social support to patients dealing with complex medical conditions. Additionally, AI tools are being used to help author patient notes such as alerting them about test results and next steps. Research on the deployment of such tools shows promise. Studies note that enhanced chatbots are relatively able to suffice patient queries regarding health conditions and provide resources, and that chatbots can help monitor disease progression and assist patients in self-care for diseases like depression and diabetes (Islam et al., 2023; Nassar et al., 2023). While there is promise there is also peril as the lack of human interaction can comprise a full assessment of mental health disorders where nonverbal cues are critical, and popularized stories of nonmedical AI chatbots making inappropriate recommendations to individuals with mental health concerns give pause to wide application of such technologies.

Here again, the potential for enhancing the patient–doctor relationship is dependent on accuracy and performative efficiency. Outsourcing aspects of patient triage and communication to AI technologies are proposed to allow clinicians to have more time to spend engaged in the patient–doctor encounter and thus deliver the intangibles of patient-centered care, more completely address health concerns, and build a stronger rapport. And if these tools are accurate then the reduced need for oversight can lessen physician cognitive burdens as well whilst supporting better patient care. Indeed this promise was heralded in a study where chatbots outperformed clinicians in responding to medical questions (Ayers et al., 2023). In considering models of the patient–doctor relationship, again it appears that such AI usage would support the informative, interpretative, and deliberative models.

Potential threats to the patient–doctor relationship

In considering how the incorporation of AI tools and technology may threaten the patient–doctor relationship, the most obvious threat is for AI to replace the doctor. The patient–doctor relationship cannot be had when one partner is not human. Doctoring is not simply functioning as a purveyor of biomedical information, or synthesizing available data to make a diagnosis or offer treatment recommendations. It is about recognizing and responding to the needs of the human being afflicted with a malady. The patient is a full human being with physical, psychological, social, and spiritual components *ala* the biopsychosocial spiritual model of human health (Sulmasy, 2002; Saad et al., 2017). Healing occurs in the context of a bilateral patient–doctor relationship within which the patient's multiple dimensions as a human being are acknowledged by a clinician who is similarly multidimensional and invests his or her full being to attend to the patient's needs.

Certainly, in the context of a patient–doctor relationship the physician invests his or her entire being to address the patient's malady, an AI tool is but a poor substitute given its lack of a multidimensional existence. To be sure, contemporary healthcare is compartmentalized as different specialists focusing on different dimensions of the malady and/or its implications for specific organ systems. Moreover, beyond physicians social workers, chaplains, psychologists and others attend to different dimensions of the patient's being as it is affected by the disease. Nonetheless attending to a patient holistically requires a response that is attuned to the multiple dimensions of the human being. And that response in our view requires the physician to be a human actor. Indeed by definition, the patient–doctor relationship involves human beings on both ends.

Said more plainly we see the principal threats of AI implementation in healthcare to be related to the reductionism of the human elements of healing in *supplanting the doctor role* and *considering the patient to a biological black box of inputs and outputs*. As noted above, much of both the promise and peril of the uptake of AI technologies lies in their patient-facing deployment. When used as an adjunct to physicians, AI tools can take over more "menial" tasks related to visit documentation and patient notifications, they can also function as triage tools and analytical supports. When AI is used alongside the clinical team the hope is that the physicians will have more time to invest in the patient—doctor relationship. They can move beyond the repudiated paternalistic or somewhat physician-divested informative models which are borne out of the need to be ever more efficient in patient care. Rather the higher ideals of the deliberative and interpretive models involve investing time in understanding one's own and the patient's values and subsequently accommodating each other along the treatment pathway. If AI reduces physicians' administrative burdens then these higher ideals may be reached. Yet, some commentators see this aspiration of time being added back into the patient—physician encounter through the adoption of AI as a romantic fantasy. Rather, they argue, the industrial value of efficiency would require that physicians see a greater number of patients as some of their more laborious tasks are given over to AI (Niel & Bastard, 2019; Sparrow & Hatherley, 2020). In order to address healthcare inequities resulting from a lack of access, patient panels will increase in physicians would increasingly outsource the labor of diagnosis and treatment recommendation to AI tools thus becoming wholly party to the informative model of the patient—doctor relationship. AI adjuncts would supplant physician cognitive functions thus removing a human element within the clinical encounter.

The substitution of the human doctor, and the related ontological reduction of human elements of a patient—doctor dyad in clinical settings is already envisaged. For example, a recent study by Ayers et al. compared chatbot responses with those of physicians to medical queries on a public social media forum. Blinded evaluators rated the responses in terms of quality and empathy. Over the course of 195 questions and responses, chatbot responses were rated significantly higher in terms of quality and empathy (Ayers et al., 2023). These surprising results, that is, that chatbots can provide higher quality medical information than physicians and are also perceived as more empathetic, may herald greater usage in the near future. These sorts of studies are particularly troubling for several reasons. Empathy is the ability to identify with and/or understand another's plight and perception. It is a capacity that can arise out of being in analogous situations and/or having the same emotive and rational processes of interpreting situations. In the context of the patient—doctor relationship, empathy is a skilled response characterized by caring concern for the patient that is accompanied by strong motivation to improve the patient's well-being (Singer & Klimecki, 2014; Jeffrey, 2016). Empathy is arguably the cornerstone of person-centered care and an empathetic doctor provides healing to the psychosocial and spiritual aspects of the patient. With this conceptualization in mind, it is impossible for AI technology to be empathetic. It has neither the faculties of interpretation of experiences, nor the lived experiences themselves, to be truly empathetic. Nor can a piece of technology care. Studies such as these make categorical and measurement errors by considering the exhibition of something like empathy or care and concern to be the actual thing in and of itself. In this way, empathy as a capacity involving social, cognitive, and emotional processes is sufficed by a mimic. In studies such reductionism is on display on the patient's side as the human need for empathy to be exhibited by a clinician is reduced to being able to measure perceived empathy on a scale, the physician's offering of empathy is reduced to a technology being able to be perceived as empathetic, and empathy as a human skill is reduced to crude technological imitation.

Relatedly, the patient–doctor encounter involves moral decisions. In the paternalistic, deliberative and interpretive models of the patient–doctor relationship the physician must make a moral judgment about what is right for the patient. Such discernment requires experience and practical wisdom. While an AI tool may be able to synthesize vast amounts of data it cannot have experience in accompanying patients along a disease course. Similarly, while AI algorithms can maximize certain values to make predictions about "best" treatments, for examle, prioritizing longevity over quality of life, they can never exercise prudence. Technologies are not programmed, nor are they judged by, how well they achieve some moral standard. Rather they are designed to and evaluated by how accurately and efficiently they provide a service. On the other hand, being a "good" doctor, invites clinicians to excel morally and to exhibit inflorescent dignity as they live out the highest internal goods of the profession. Until we get to sentient AI technologies, and perhaps even not then, can AI be a substitute for human moral excellence. We are deeply concerned that the deployment of AI technologies such as prediction algorithms may lead physicians to abdicate their role in shared decision-making thus relegating the profession to the informative model of a patient–doctor relationship grounded in a consumeristic model of healthcare.

Moving away from the physician and to the patient, the wholescale adoption of AI tools and technologies may, inadvertently, instantiate a conception of the human being, in this case the patient, as a biological black-box of inputs and outputs and a data repository. Recall that the accuracy and efficiency of AI tools in diagnosis and prognostication are wholly dependent on data access. ML algorithms "learn" based on the data inputs, when data quality is high then biases and errors are reduced. Most AI tools have access to limited population-level data as they assist physicians in making treatment recommendations. The gold mine for AI technologies is to be able to "personalize" recommendations by having access to individual patient data that speaks to their biological composition, prior history, and medical values. Commentators note that accurately attending to the social dimensions of health requires data on the patient's social status and behaviors. Some of these data points may exist outside of the traditional medical record. Our concern here is that in a future where AI technologies are used to make predictions about treatment courses, greater amounts of data will be needed to be necessary for both individual and population levels. As this happens the patient, a multidimensional human being, becomes rendered by AI into data points across time. And the life experiences of the human being become experimental conditions that influence changes in data curves. This matrix-like rendering of humans and life gives us pause. For one there is a positivistic ontological reductionism that undergirds such a view. The intangible and unmeasurable aspects of a human being and of human life are absent and unacknowledged. In such a data model for biomedicine, where would human flourishing figure? How would feeling "blessed" despite poor social conditions and health metrics be acknowledged? An increased reliance upon AI in healthcare may diminish the human equation in health and healing.

As healthcare grows ever more reliant on AI tools and technologies, we remark on how the context, nature, and quality of patient—doctor relationships may be altered (Bauer, 2004). Further research and deliberation are needed to better understand the implications of increasing AI use in healthcare. Hence, we call for multidisciplinary research involving social scientists, theologians, AI scientists and engineers, clinicians, and bioethicists to come together to understand the ethical problem space and generate a vision for how to appropriately incorporate AI in contemporary healthcare whilst programming the human dimensions of the patient—doctor relationship, health and healing.

Summary and recommendations

The potential impact of widespread AI implementation in healthcare on the patient—doctor relationship remains uncertain. As mentioned above, perspectives on this matter vary, ranging from enthusiastic appraisal of increasing healthcare access and enhancing patient satisfaction by giving back time to the patient—doctor encounter to concerns about AI dehumanizing medical practice and introducing a new paternalistic care model. The precise effect of AI in healthcare remains unclear as implementation research is needed; however, AI integration will undoubtedly challenge patient—clinician interactions as AI use could pose significant communication barriers and overreliance on AI might diminish interaction between physicians and patients. Indeed there is also a possibility that consumers might resist adopting AI applications due to their need for human social interaction during service interactions (Gursoy et al., 2019). Therefore, clinicians will need to learn how to collaborate with AI systems for healthcare delivery, and patients must be educated in AI use to overcome their technological fears and improve acceptance. Thus, prior to the broad integration of AI, preparatory research and education is necessary. Guidelines for evaluation should be established to enable regular audits and continuous monitoring, assessing AI's impact on patient safety, communication, satisfaction, and doctor—patient relationships. Below we comment on the need for education.

Education

Medical education

A strategy to enhance AI adoption in healthcare involves implementing educational materials or curricula for both patients and physicians. Medical training should emphasize how to effectively engage with AI systems and how to provide compassionate patient care at the same time (Srivastava & Waghmare, 2020). Incorporating AI-related topics into medical curricula can equip medical professionals with fundamental knowledge of the technology and its ethical dimensions. Medical professionals have highlighted the importance of fostering collaboration between medical schools and faculties of engineering and computer science, recognizing it as a transformative step in integrating AI into medical education (Alanazi et al., 2023). Oman, for instance, has already taken strides by incorporating AI learning objectives and workshops into its medical curriculum. In recent years, the region has observed a surge in the number of AI-related conferences, symposia, and summits. This trend reflects a growing commitment to enhance the understanding and readiness of healthcare providers and medical students regarding the utilization of these tools and the ethical considerations associated with them.

Moreover, medical education should emphasize patient-centered care by redoubling efforts to teach communication and soft skills. Beyond AI literacy, empathy and compassion must be fostered and taught throughout the curriculum, remaining central to medical practice. As explained by Aagrew and Jenkins, in the future, the best doctor will be the one who has a deep understanding of how it "feels" to be a patient along with knowledge of new AI technologies (D.C. & T.R., 2015).

Some countries and regions have already started integrating AI courses into medical education, addressing the current lack of awareness and utilization of clinical AI among doctors, which also fosters AI's further advancement. It is important to recognize that government policy support is crucial for effective AI education. However, supportive policies require more robust evidence of the effectiveness, feasibility, and economic viability of AI in medical education (Li et al., 2020).

Patient's education

On the other side, patients should possess adequate knowledge about how these tools are being used in healthcare delivery, and their rights and concerns should be clearly addressed and communicated. Some commentators assume that AI will reinforce "a customer-service relationship" in healthcare which may not be an optimal model for healthcare delivery. Furthermore, Esmaeilzadeh has reported patients concerns over how AI might compromise transparency, privacy, trust and accountability (Esmaeilzadeh et al., 2021).

In the context of GCC countries, effective communication could pose a significant challenge, given that a majority of the current tools lack support for the Arabic language. Furthermore, in the GCC countries, there exists a noticeable lack of confidence among the public when it comes to sharing data which may reduce the algorithmic efficacy of some AI tools (Bani Issa et al., 2020). The public is skeptical about potential breaches of privacy and the associated stigma with chronic diseases which was reported earlier as well (Esmaeilzadeh et al., 2021). Collectively this might potentially breed mistrust towards doctors. Consequently, it is critical to fortify legislation and ethical frameworks concerning data sharing and technological utilization. Notably, Saudi Arabia has taken a positive step by unveiling a draft version of its forthcoming AI Ethics Principles and inviting public feedback through consultations. Furthermore, to ensure maintaining patient centricity in AI-augmented healthcare services, it is essential to establish programs that consistently assess patient satisfaction with AI tools in practice and their safety to ensure the quality of services and promote improvements in care.

Healthcare policy

Finally, the role of policy regulation cannot be overemphasized. As noted above AI and ML models are fully dependent on the data, they have access to. Algorithmic biases and inaccuracies are encountered when the underlying data used to train systems is systematically flawed or partial. Dolling of AI as an adjunct to diagnosis and prognosis requires GCC countries to create policies that allow for greater freedom of informational exchange across and between healthcare facilities, for example, from medical records, as well as from private companies that may develop patient-facing wearables. Balancing privacy and access is key in this policymaking realm and has significant implications for AI tools in healthcare. Another area of policy development that is key to the usage of AI tools and technologies in healthcare relates to liability. Who will be liable should AI tools make inaccurate predictions and patients' suffer? Is the doctor liable? Is the maker of the technology? Are both? Here too policymakers will have to carefully consider tort protections and commercial interests whilst focusing on enhancing the patient—doctor relationship. If physicians feel insecure in using AI to assist in healthcare because they are saddled with greater liability should they use them, then the technology will have reduced uptake. Yet, here too human culpability cannot be left out of the equation. As we enter a new era of AI-assisted nuanced discussions on healthcare policy and law are sorely needed.

Disclosure

In accordance with the Committee on Publication Ethics (COPE) position statement of February 13, 2023 (https://publicationethics.org/cope-position-statements/ai-author), the authors hereby disclose the use of the following AI models during the writing of this article. GPT-3.5 (OpenAI) for checking spelling and grammar.

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CHAPTER 18

Ensuring governance for quality, safety, and efficiency of medicines in the state of Kuwait: a call for action

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Introduction

Medicines are essential for maintaining and improving the quality of life, and well-coordinated medicine management contributes to reducing the national burden of diseases and health costs (Lewis et al., 2020). At each step of the medicine usage process, including procuring, prescribing, administering, and monitoring, there is a possibility of errors or misuse occurring (Alsaleh et al., 2017). The errors or misuse of medicines could be related to health products, procedures, labeling, packing, professional practice, self-medication, administration, and monitoring. Unawareness of the rational use of medicine leads to severe consequences (Chouhan & Prasad, 2016). One of the greatest issues of self-medication is the misuse or overuse of antibiotics (WHO, 2015). The use of medicament by self-medication has been increasing today (Chouhan & Prasad, 2016). The self-medication practice prevalence is common, varying from 32.5% to 81.5% globally (Kifle et al., 2021). According to the World Health Organization (WHO, 2020), antibiotic resistance is one of the biggest threats to global health, being chosen as one of the top ten threats to global health in 2019 (WHO, 2019). Antibiotic resistance is widely accelerated by the misuse and overuse of antibiotics (WHO, 2020). There are several reasons why self-medication has increased over time, including "ready to access to drugs," "greater availability of medical goods in markets" (Chouhan & Prasad, 2016), and inadequate surveillance and insufficient regulation of the use of antimicrobial medicines (WHO, 2015).

Comprehensive national plans and surveillance mechanisms are regarded as one of the ways to fight antimicrobial resistance and drug misuse, despite few countries showing such plans and mechanisms (WHO, 2015). The Eastern Mediterranean Region of

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WHO, which comprises 21 countries, including Kuwait is facing significant challenges in the control over medicine due to the lack of a national coordinating mechanism, including Kuwait (WHO, 2015). Several countries in the Middle East lack functional and coordinated national pharmacovigilance programs (Lemaya et al., 2018). Only a few countries in the Eastern Mediterranean Region of the WHO had regulations for quality standards but with limited enactment (WHO, 2015). Pharmacovigilance is one of the main tools for improving quality, safety, and effectiveness for maximizing patient therapeutic outcomes (WHO, 2002). Medicines management is necessary to maintain a healthy and efficient national health system. Medicines management was defined in general by UK hospitals, focusing on the flow and safe use of medicines in the National Health Service (NHS) and hospitals (RCN, 2020), being defined as a system of processes and behaviors that determines how medicines are used by the national health system and patients (RCN, 2020) in the matter of the clinical cost-effective and safe use of medicines to ensure patients get the maximum benefit from the medicines they need, while at the same time minimizing potential harms (RCN, 2020). Like the UK, Kuwait has implemented the National Health Service framework as the backbone of its national health system since the 1960s (Chun & Salman, 2019). Although the Kuwait Drug and Food Control (KDFC) has implemented several pharmacovigilance initiatives, including guidelines for marketing authorization holders and adverse drug reaction reporting, it has not yet been fully implemented (Lemaya et al., 2018). Only 34.2% (Alsaleh et al., 2017) and 27.8% (Lemaya et al., 2018) of physicians and pharmacists in Kuwait report adverse drug reactions (ADRs), although 74.6% of physicians have identified ADR during their daily practice (Alsaleh et al., 2017).

The burgeoning realm of digital health policy stands as a pivotal pillar in revolutionizing healthcare systems worldwide, including Kuwait. As technological advancements continue to shape various facets of society, their integration into healthcare policy becomes imperative. Digital health policies encompass a broad spectrum of initiatives, including the utilization of telemedicine, health information technologies, electronic health records (EHRs), and innovative data analytics. The significance lies not only in modernizing healthcare delivery but also in enhancing accessibility, efficiency, and patient-centered care. By fostering an ecosystem that amalgamates technology with healthcare, these policies aim to alleviate existing systemic challenges, empower patients, streamline operations, and ultimately foster improved health outcomes.

The healthcare landscape in Kuwait represents a blend of public and private sectors aimed at providing comprehensive medical services to its population. The public healthcare system is primarily managed by the Ministry of Health (MOH), offering subsidized or free healthcare services to Kuwaiti citizens. The sector comprises various primary healthcare centers, district hospitals, and specialized medical facilities, striving to deliver equitable and accessible care to the population. However, challenges persist, including disparities in healthcare quality between regions, overcrowding in hospitals, and a heavy reliance on expatriate healthcare workers. The private healthcare sector in Kuwait complements the public system, offering a range of services, from general practitioners to specialized clinics and hospitals, catering to both citizens and expatriates, often with higher costs but perceived higher quality and shorter waiting times.

Statistics reveal Kuwait's healthcare progress, yet also highlight existing areas for improvement. For instance, according to the World Health Organization (WHO), Kuwait boasts an impressive physician-to-population ratio, but disparities in healthcare access and distribution persist, affecting timely access to specialized care for certain demographics. Despite investments in healthcare infrastructure and services, chronic diseases like diabetes and cardiovascular conditions pose significant health burdens. As Kuwait continues its healthcare journey, efforts are ongoing to address these challenges and bridge gaps in healthcare accessibility and quality across its diverse population.

Kuwait has embarked on a transformative journey by implementing several digital health initiatives to modernize its healthcare infrastructure. One such initiative is the Kuwait National Electronic Health Record (NEHR) system, aimed at centralizing patient health information digitally. The NEHR initiative seeks to enhance care coordination among healthcare providers, improve patient safety through accurate and accessible medical records, and facilitate better clinical decision-making. Additionally, the implementation of telemedicine services has gained momentum, particularly in remote areas, allowing patients to consult healthcare professionals virtually and receive timely medical advice or treatment, thereby reducing geographical barriers to healthcare access.

In alignment with these initiatives, Kuwait has developed comprehensive policies and regulations to govern the digital health landscape. The Ministry of Health (MOH) oversees the formulation and implementation of these policies, ensuring compliance with standards and protocols for data privacy, security, and interoperability. These policies aim to establish a robust framework for the secure exchange of health information among healthcare entities while safeguarding patient confidentiality. Moreover, Kuwait's government has enacted regulations to encourage the adoption of digital health technologies, fostering innovation and investment in this burgeoning sector while ensuring adherence to ethical and legal considerations in healthcare delivery.

Kuwait's digital health sector, while promising, faces several challenges impeding its full-scale integration into the healthcare system. One significant hurdle is the need for a robust infrastructure to support the widespread adoption and implementation of digital health technologies. This includes ensuring reliable internet connectivity, especially in remote areas, and investing in adequate technological resources for healthcare facilities across the country. Additionally, issues related to data privacy, security, and standardization pose challenges. Protecting sensitive health information and establishing interoperability standards for seamless data exchange between different healthcare systems are vital but complex tasks that require comprehensive regulations and infrastructure.

However, amidst these challenges lie significant opportunities for advancement and growth in Kuwait's digital health landscape. The evolving technological landscape presents opportunities to innovate and create tailored solutions to address healthcare disparities and improve access to quality care. Leveraging artificial intelligence (AI), machine learning, and big data analytics offers immense potential in optimizing healthcare delivery, predictive analytics for disease prevention, and personalized medicine. Furthermore, strategic partnerships between the public and private sectors, coupled with investments in research and development, can foster a vibrant ecosystem for digital health innovation and entrepreneurship, potentially positioning Kuwait as a regional leader in healthcare technology.

The integration of digital health stands as a pivotal catalyst poised to revolutionize Kuwait's healthcare landscape and shape its future. By embracing digital health initiatives, Kuwait can unlock a myriad of opportunities that transcend traditional healthcare boundaries. Enhanced accessibility to healthcare services, particularly in remote or underserved areas, becomes feasible through telemedicine and remote monitoring technologies, ensuring equitable healthcare access for all citizens. Moreover, the seamless sharing of EHRs among healthcare providers fosters a cohesive and patient-centric approach, leading to more informed clinical decision-making, reduced medical errors, and improved patient outcomes.

The transformative power of digital health extends beyond accessibility to encompass efficiency and cost-effectiveness within the healthcare ecosystem. Integration of advanced technologies such as AI-driven diagnostics and predictive analytics empowers healthcare providers to deliver proactive and personalized care, potentially curbing the prevalence of chronic diseases through early detection and tailored interventions. Additionally, by streamlining administrative processes and optimizing resource utilization, digital health initiatives have the potential to mitigate healthcare expenditure while simultaneously improving the quality and efficiency of care delivery, aligning with Kuwait's aspirations for a sustainable and resilient healthcare system.

The aim of this article is, at the national level, to promote the safe, cost-effective, and evidence-based use of medicines focused on prescribing matters necessary to deal with pharmaceutical affairs smoothly and market safety management, including adverse drug reactions, thereby contributing to the improvement of the national public health.

Kuwait's medicine management system: status and issues

One of the most serious medicines management issues in Kuwait is that antibiotics and hormone-containing products can be purchased from pharmacies without physicians' prescriptions. The second issue is that the medicine management process in the private sector differs from that in the public sector. Fig. 18.1 shows the medicine management system and flows in Kuwait. The structure of clinics and hospitals comprises primary care

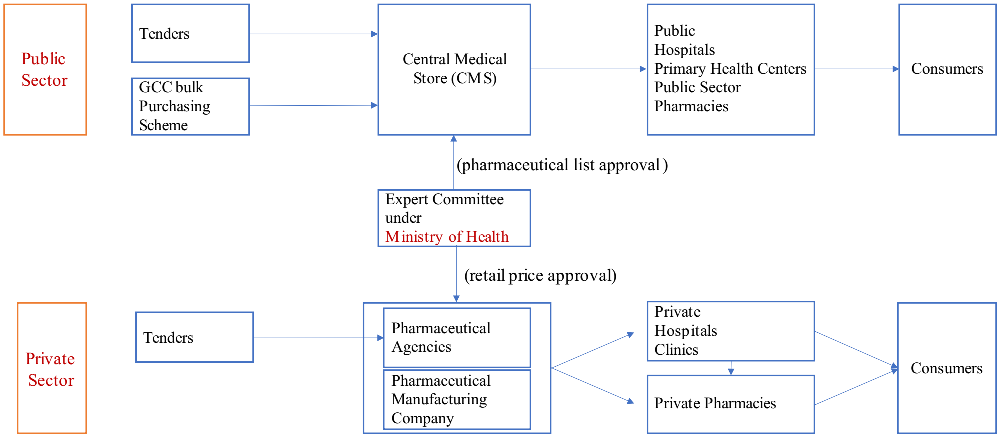

Figure 18.1 Medicine management and flows in Kuwait.

polyclinics, specialized polyclinics, and general and specialized hospitals (Chun & Salman, 2019). Although there are no formal national medicine policy documents, the Central Medical Stores (CMS) is an official government body in charge of medicine management, listing public sector medicines in collaboration with Ministry of Health expert committees (Ball et al., 2005). CMS distributes public sector medicines. The CMS procures medicines through competitive tenders and the GCC bulk purchasing scheme.

Public sector procurement of medicines in Kuwait is still effective and efficient, increasing procurement of generics in the public sector (Chun, 2018). But medicine prices in the private sector are almost twice those in Australian PBS reference prices (Ball et al., 2005). Therefore, the high price of medicines in the private sector is a public concern in Kuwait. Although there is a significant concern about openness in medicine pricing, the detailed procedures to check and control medicine prices amongst the pharmaceutical companies are not well designed or implemented (Ball et al., 2005). Medicines are only dispensed in the public sector based on prescriptions by medical practitioners. If a medicine is required that is not available in the public sector, the patient must purchase it from private pharmacies. In the private sector, medicines are imported through registered pharmaceutical agencies. A single pharmaceutical manufacturing company in Kuwait (Kuwait Saudi Pharmaceutical Industry Company) produces generic products (Ball et al., 2005). Private retail pharmacies order directly from the agencies. Most medicines are available without prescriptions in the private sector, except psychotropic and narcotic preparations, corticosteroids, antibiotics, and other specific medicines. The government sets retail prices, and the price must be displayed on the outer packaging or container of the products.

In summary, there are two different systems of medicine management for the public and private sectors triggering over usage of higher price medicines; and causing a negative perception that medications prescribed by the public sector are not as good as those prescribed by the private sector. Additionally, there is no precise monitoring and surveillance system for medicine use. The current practice between prescribing and dispensing medicines between physicians and pharmacists does not function effectively due to the disconnect or separation of prescribing and dispensing information, which haphazardly allows anyone to purchase Ethical The Counter Drugs (etc) such as antibiotics and steroids without any restrictions. Notably, there is no specific compulsory obligation to report adverse drug reactions. The weak functions of agencies that determine all medicine management processes are issues arising in Kuwait's medicine management system.

The medicine management system for Kuwait

For organizing the medicine management system at the national level as a whole, it is necessary to consider five dimensions of the flow of medicines: (1) registration system for medicines; (2) process of marketing; (3) decision-making for the retail prices; (4) supply and consumption information of drug use; and (5) safety assurance system of the medicine usage (Choi et al., 2012; KIHASA, 2017; Lee et al., 2014; You et al., 2015). Thus, Fig. 18.2, the model of the medicines management system for Kuwait, shows five specific areas and four flows: medicine registration system (Route A and C); essential medicine management system (Route B); pricing system for retail prices of medicine (Route A); distribution and information gathering system (Route D); and

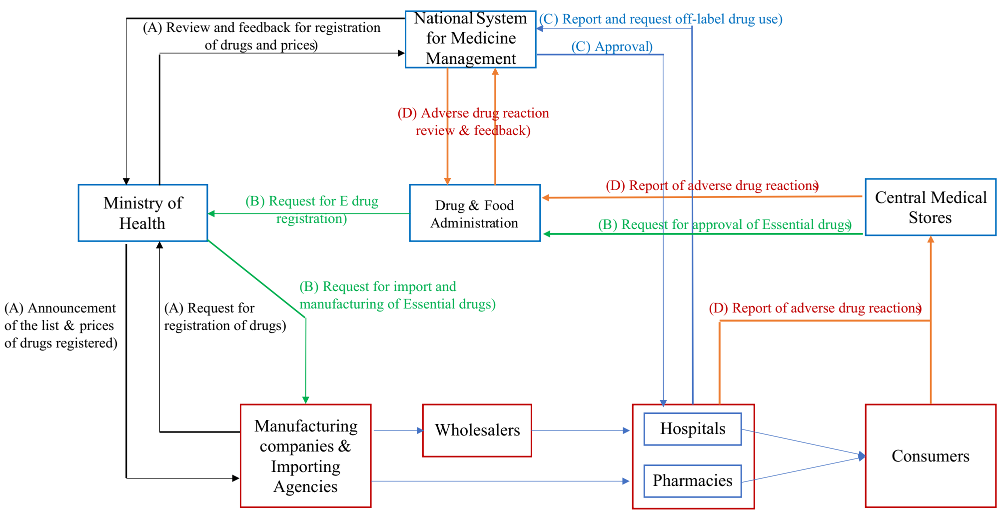

Figure 18.2 A recommended model for Kuwait's medicine management system.

medicine safety and risk management system (Route D). The governance structure is composed of the four public authorities: Ministry of Health, National System for Medicine Management, Drug & Food Administration, and CMS, collaborating with each other systematically and functionally to ensure providing the best, cost-effective, and safe medicines to patients.

Preconditions

Managing medicines requires two preconditions: enacting regulations and a policy addressing the separation of the prescribing and dispensing of medicines, and establishing the National System for Medicine Management (NSMM). NSMM enables control in one unified system for both public and private sectors, enabling managing all the information on registration, marketing, prices, and distribution of medicines at the national level well. Through the regulation for separation of prescribing and dispensing medicines, medicine safety and risk management will be adequately ensured. The model recommended has been made considering conditions the two prepositions be accomplished. The CMS is an official government body in charge of medicines management. The Drug and Food Administration is the main administrative body under the Ministry of Health. The National System for Medicine Management is a hypothetical body operating national level controlling tower of medicines. The Ministry of Health is responsible for governing medicine management and related affairs. For instance, to ensure the appropriateness in nature, state, quality, and storing method of medicines and similar matters, the Ministry of Health can publish the Kuwait Pharmacopoeia and announce it publicly.

Medicine registration and pricing

Route A in Fig. 18.2 shows the medicine registration flows and pricing mechanism. A person who intends to manufacture and sell a drug substance of a new drug or a drug substance that is determined and publicly notified by the Ministry of Health files registration for matters such as its components, name, and manufacturing methods with the Drug & Food Administration. The National System for Medicine Management examines whether the issues of registration under paragraph satisfy the criteria, informs the relevant of the examination results, records the details of examination in the drug substance register, and keeps the register. In such cases, the Ministry of Health publicly notifies the issues, such as the components and manufacturer of the relevant drug substance. For a person who intends to obtain marketing approval, or file a marketing notification of the drug, and a person who intends to conduct clinical trials using a drug, the Ministry of Health examines standards for preparing documents necessary for marketing approval, notification, and approval in advance. Upon receipt of a request, the Ministry of Health confirms such and informs the applicant of examination results in writing. Drug substances registered pursuant to the paragraphs be deemed approved or notified. To determine the prices of each medicine (route A in Fig. 18.2), practical surveys need to be conducted to identify real transaction prices for both wholesale and retail.

National essential medicine management

The term "national essential medicine" means a medicine essential for health and medical treatment, such as disease control, prevention of radiation disease, etc., but a stable supply is difficult only by the market function (KIHASA, 2017). Route B in Fig. 18.2 shows the pathway of the national essential medicines management and the flow of the works of orphan and essential medicine management. The Ministry of Health, Drug & Food Administration, and Central Medical Stores perform the following affairs regarding national essential medicines: formulating and implementing comprehensive policies for a stable supply of national essential medicines; supporting the establishment of a stable supply base of national essential medicines, research and development thereof, and safe use thereof; and other necessary affairs relevant to the stable supply of national essential medicines. The Central Medical Stores perform the work of providing information with respect to national essential medicines and supplying, including duties of preparation and dosage of medicines (route B in Fig. 18.2).

Information reporting channel of medicine use and market flow

Route D in Fig. 18.2 also shows the surveillance system of medicine use and market flows. Each person, who intends to engage in the business of importing medicines, files a report on the importation business with the Ministry of Health and obtains marketing approval from, or files a marketing notification with, the Ministry of Health for each product. No person other than pharmacy founders can sell or obtain medicines for sale. A person who has received marketing approval for medicines, an importer, or a medicine wholesaler who has supplied medical institutions, pharmacies, and medicine wholesalers with drugs submits details of such supply to Central Medical Stores. The Central Medical Stores requests the state, local governments, and other public organizations to provide necessary data for efficiently controlling information on the distribution of medicines. And the State, local governments, and other public organizations, upon receipt of requests, comply with such requests.

Hospitals, clinics, health centers, and pharmacies report purchasing and consumption information of all medicines to the National System for Medicine Management. The Minister of Health and the Drug & Food Administration order the Central Medical Stores to report the current status of management and distribution of medicines. The Central Medical Sores performs information control of the distribution of medicines for collection, investigation, processing, utilization, and provision of information on the distribution of medicines, such as manufacture, importation, supply, and details of the use of medicines and require it to perform such affairs. A person who has obtained marketing approval for medicines, an importer, or a medicine wholesaler who has supplied medical institutions, pharmacies, and medicine wholesalers with drugs submits details of such supply to the Central Medical Stores.

Management of the off-label medicine use

Route C in Fig. 18.2 is a pathway to regulate and secure off-label medicine use, including a regulatory structure, safety control before and after off-label use, and information management. The Ministry of Health and the Drug & Food Administration ordered the Central Medical Stores president to report the current status of the management and distribution of medicines.

Medicine safety and risk management

Route D in Fig. 18.2 explains the medicine safety and risk management system. A person who has obtained marketing approval for medicines has to perform the duties of postmarketing safety control, such as re-examining new medicines, re-evaluating medicines, and reporting side effects. Where a medicine manufacturer, a person who obtained marketing approval, or an importer intends to advertise medicines manufactured or imported by oneself, they undergo deliberation by the Drug & Food Administration. A person who has obtained marketing approval for drugs, an importer, a medicine wholesaler, a medical institution founder, or a pharmacy becomes aware of an adverse event suspected of having been caused by medicines, such as a disease, disability, death, or other event relating to the safety and effectiveness of other medicines, they need to report thereon to the Central Medical Stores. The Central Medical Stores report to the Drug & Food Administration the matters on which they have received a report from the official routes above.

The Central Medical Stores performs the duties of collecting, analyzing, assessing, and supplying various information on medicine safety, such as side effects of medicines, information on marketing approval, and information on marketing notification. CMS conducts the following projects commissioned by the Ministry of Health and Drug & Food Administration, including investigating and identifying causal relationships of side effects of medicines, such as pharmaceutical mishaps; establishing a medicine safety information management system to gather and manage medicine safety information; collecting, analyzing, assessing, managing, and supplying medicine safety information; and conducting the investigation, research, education, and publicity aimed at developing and utilizing medicine safety information.

Recommended steps for health digitization

Digital transformation has the ability to improve clinical efficiency, reduce costs, and provide patients with hyper-personalized treatment. To be effective, digital initiatives must integrate all aspects of the organization, including technology, management, and culture.

Best practises imply that healthcare institutions seeking to transform digitally must take a comprehensive approach and commit as an organization to developing and delivering a digital transformation plan that has data at its core.

Initial diagnosis

As a first step, healthcare organizations should conduct a company-wide review of their present systems to identify pain points, major areas for improvement, and potential for change.

Then, healthcare organizations must create wish lists for each department, prioritize and offset them against available funds, and establish a set of key performance indicators (KPIs) for tracking and evaluating performance, such as ROI, staff and patient satisfaction, as well as the Hospital Customer Assessment of Healthcare Facilities and Systems (HCAHPS) ratings—a standardized survey instrument and data collection methodology utilized to evaluate patients' perspectives on hospital care.

For an effective digital transformation roadmap, healthcare institutions should take a three-dimensional approach that considers people—those who provide and receive services; processes—or usability; and technology—tools that improve the running of operations and the delivery of care. Institutions must develop and empower interdisciplinary teams comprised of clinical, IT, and facility experts to drive this review and, later, execution. Forming these teams also ensures organizational alignment, which is critical for maintaining leadership buy-in and consistency in execution across the organization.

Goals, priorities, and key performance indicators

Then, healthcare organizations must create wish lists for each department, prioritize and offset them against available funds, and establish KPIs to measure and track performance, such as ROI, staff and patient satisfaction, and Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) ratings—a standardized survey instrument and data collection methodology used to measure patients' perspectives on hospital care. Setting clear and attainable goals is crucial in dealing with executive-level issues.

Mapping of technologies and processes

The next stage is to determine which technologies and/or processes are required to accomplish those KPIs, as certain targets will necessitate the implementation of new processes, others will necessitate the integration of new technologies, and the majority will rely on a combination of the two.

For an effective digital transformation roadmap, healthcare institutions should take a three-dimensional approach that considers people—those who provide and receive services; processes—or usability; and technology—tools that improve the running of operations and the delivery of care.

Security and privacy

The inherent data security and privacy risks in digital health are a big obstacle to adoption. The fact that health institutions collect data that includes sensitive information other than medical histories, such as genetic information, financial histories, and purchase habits, adds to the risk for users.

The connection with external suppliers, in particular, is a significant source of concern for healthcare institutions, owing to the latter's limited internal capacities, lack of data science know-how, and reliance on outsourcing. By forcing vendors to conform to specified security requirements, healthcare organizations may examine and manage risk across the whole value chain. Healthcare institutions should also implement fair and transparent data custodianship and access policies and practises, as well as guarantee customers' ability to access, alter, or delete any individually identifiable health information.

Continuous innovation and execution

The digital solutions and processes should be rigorously tested iteratively throughout the initial phase of digital integration. Long term, the transformation plan should evolve into a continual feedback loop aimed at improving and augmenting the institution's digital quotient.

The successful implementation of a transformation strategy is largely dependent on careful monitoring of its KPIs, adherence to the rules and regulations, and good collaboration among the parties involved. Failure to keep track of progress could be disastrous, which is why it is critical to explicitly designate points of accountability as well as meaningful rewards.

Companies that embrace digital agility, on the other hand, will gain competitive advantages over those that do not. Agility enables businesses to continuously modify their digital strategies depending on outcomes and feedback, allowing them to experiment, adjust, and enhance their approach in iterations.

Furthermore, organizations should nurture an entrepreneurial spirit in order to capitalize on emerging opportunities and new avenues for digital transformation. This is accomplished by fostering an innovative and risk-tolerant culture that encourages and rewards original ideas, whether they are for developing new processes, goods, or services with the potential to generate additional revenue streams.

Digital disruptors and collaboration

The demand for digital health is increasing as technology becomes more accessible. Small to Medium Enterprises (SME), particularly startups, must capitalize on their natural advantage in delivering in-demand tech-focused, patient-centric solutions faster than larger incumbents, because they are less burdened by slow bureaucracy and large, difficult-to-update legacy systems.

SMEs and startups can seek opportunities through collaboration with large healthcare enterprises looking to foster their own digital transformation—whether through partnerships, mergers, or acquisitions—especially because these large organizations frequently lack the technical capabilities and culture to drive their transformation.

Furthermore, companies should look for ways to collaborate with their competitors, as they often face similar issues. According to a study conducted by the Multidisciplinary Digital Publishing Institute26, the benefits often outweigh the drawbacks—competitors who collaborated for three to five years had more than a 50% likelihood of jointly cutting expenses.

To thrive, compnies must prioritize cultivating and building trust with both consumers and enterprises, whether they are developing their own customer-facing solutions or developing technology that plugs into the healthcare value chain. Companies can also consider employing experienced talent, especially during key phases of rapid growth or expansion.

Conclusion

The purpose of national medicine management is to prevent risk factors that may occur in all stages of production, import, distribution, prescription, dispensing, and administration, and to provide quality and safe medicines to the people. Therefore, medicines should be managed in the professional domain and within the scope of the national health system. In addition, the medicine supply and demand plan should be reflected in the national mid- and long-term health and medical plans.

The reasons loopholes occur in the medicines management process, despite the Kuwaiti government's unremitting efforts, are the lack of a comprehensive plan for medicine management and the absence of policy, institutional, and legal capacity to manage medicines professionally. However, the transformative landscape of digital health policy stands as a crucial component in redefining healthcare systems globally, including within Kuwait. As technological advancements continue to redefine societal norms, integrating these advancements into healthcare policies becomes imperative. Digital health policies encompass a wide range of initiatives, such as telemedicine, EHRs, and data analytics, aiming not only to modernize healthcare but also to enhance accessibility, efficiency, and patient-centered care.

For Kuwait's healthcare landscape, embracing digital health policies becomes paramount in addressing systemic challenges and transforming the existing infrastructure. The integration of digital health initiatives, including the Kuwait NEHR system and telemedicine services, exemplifies Kuwait's commitment to modernizing healthcare delivery and improving patient outcomes. However, challenges in digital health implementation, such as infrastructure gaps and data privacy concerns, need robust regulatory frameworks and investments in technological resources to be addressed effectively. To ensure a robust medicine management system and to position Kuwait at the forefront of healthcare innovation, it's imperative to bridge these gaps by integrating digital health strategies into Kuwait's healthcare policies comprehensively. By aligning policy measures that separate prescribing and dispensing medicines and developing national strategies for medicines management policy, Kuwait can ensure a seamless transition toward an advanced healthcare system. Policymaking actions should involve a sequence of steps and activities, ensuring meticulous policy research and implementation, to achieve desirable results. In conjunction with this, enacting, integrating, and amending relevant regulations and acts, such as the Pharmaceutical Acts and Health and Medical Service Technology Promotion Acts, becomes essential to fortify the legal and regulatory framework governing medicine management and digital health initiatives in Kuwait.

The integration of digital health policies not only promises to revolutionize Kuwait's healthcare landscape but also aims to improve healthcare accessibility, efficiency, and cost-effectiveness. By leveraging digital health tools and fostering a collaborative ecosystem between public and private sectors, Kuwait stands to achieve transformative outcomes, enhancing healthcare delivery and propelling its national health system toward a sustainable and resilient future.

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CHAPTER 19

Telehealth: business models and commercialization

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Introduction

Today, the demand for healthcare services has increased for a variety of diseases. The increased demands along with the rapid advancement in information technology indicate that there is a need for a new paradigm for providing healthcare services (Kimble, 2015; van Limburg et al., 2011). This technology has a number of advantages, and can improve patient—physician communication, information sharing between specialists, patients and researchers, and quality of care (van Limburg et al., 2011). Among different types of health information technologies, telehealth technology refers to the use of telecommunications and information technology to support clinical patient care, education and remote consultation, and includes a complex set of technologies, organizational models, clinical services and assessment tools (Weinstein et al., 2014). Telehealth is a comprehensive term that includes telemedicine and mobile health (mhealth) (Becevic et al., 2020; Pereira, 2017).

It is worth noting that the two terms of telemedicine and telehealth are sometimes used interchangeably. Telemedicine is defined as the use of telecommunications and information technology to help provide medical services such as patient care and monitoring from a distance (Edmunds et al., 2017). According to the American Telemedicine Association, telemedicine refers to the transmission of healthcare services and clinical information remotely using technology. In other words, telemedicine provides patients with access to physicians, nurses and care services at any place and time (Freed et al., 2018; Sterling & LeRouge, 2019). However, the term telehealth is broader and includes the use of information and communication technologies to provide and support different types of healthcare services, education, etc. (Becevic et al., 2020; Sisk et al., 2020; Tyson et al., 2019). In addition, while telemedicine focuses on treatment, telehealth deals with different aspects of prevention and health promotion in addition to treatment (Van Dyk, 2014).

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Since a decade ago, the provision of telehealth services has attracted the attention of health sector policymakers, hospitals, healthcare professionals, and patients, and has expanded even in developing countries (Chen et al., 2013; Ismail Zadeh, 2015). However, despite the advantages of this technology, many projects failed at the operational stage or have been limited to the testing and research phases (Chen et al., 2013; Kijl & Nieuwenhuis, 2010; Kimble, 2015; Kijl, Nieuwenhuis, & Huis in't Veld, 2010). Most of these innovations and new technologies are never presented at the market level or their presentation in the market will be accompanied by challenges. It seems that the main focus of these new technologies is on the technological/engineering aspects rather than on the real values (Kijl & Nieuwenhuis, 2010; Kijl et al., 2010; Pereira, 2017). However, the real value of innovation is in commercialization results, and success in commercialization is of particular importance (Datta et al., 2013; Simonse et al., 2011).

Examining the problems and reasons for the failure of telehealth innovations shows that in many cases, these technologies have been designed, introduced and used regardless of the important aspects of using new technology such as technical, behavioral, financial, legal and organizational issues (Chakraborty et al., 2023; Chau & Hu, 2002; Pereira, 2017; Sundin et al., 2016; Van Dyk, 2014). However, the provision of telehealth services requires the coordination of activities among a wide range of users, stakeholders, and organizations which makes the process of commercialization more complex (De Raeve et al., 2017; Mistry et al., 2014). In addition, the role of customers cannot be easily defined in the field of telehealth services, because they include different groups, such as patients, healthcare providers, hospitals, insurance companies and IT providers (Pereira, 2017; Peters et al., 2015).

To solve the mentioned challenges, various business models have been proposed to support the successful commercialization of telehealth innovations (Kijl & Nieuwenhuis, 2010). A business model is a high-level conceptual description of the activities completed to produce a new product to meet the customer's requirements. Business models help to reach value creation, value capture and value architecture. They create value, capture value by marketing, supporting and selling the product, and architecture value using a chain of activities that connects customers to the suppliers of a product (Kimble, 2015). A business model is a plan to represent a network of organizational collaborations in creating and capturing value from innovations, and business modeling is integrated into the design and development processes to enable value-oriented implementation (Kijl & Nieuwenhuis, 2010).

In recent years, new business opportunities have emerged in digital health services (Poonsuph, 2022). As a result, different business models have been introduced and used in the field of telehealth and telemedicine (Pereira, 2017; Peters et al., 2015). The value proposition, interface, service platform, organizing model, and revenue (VISOR) model (Pereira, 2017) and the CompBizMed framework (Peters et al., 2015) are two examples of these models. However, the business models and frameworks presented in developed countries may not fit with the context of developing countries (Pereira, 2017; Peters et al., 2015), and it is necessary to identify components and contextual factors affecting the business and use of innovations in a specific context.

Reasons for success and failure of telehealth projects

Although telehealth technology supports healthcare services by increasing quality, access, productivity, efficiency, and effectiveness, its implementation usually accompanied by several challenges (Van Dyk, 2014). Many telehealth projects that are successful in the pilot phase, fail in the next stages, and many mistakes are repeated during their implementations (Van Dyk, 2014). According to the literature, 50% of patents filed in the field of health technologies never become a commercial product (Lehoux et al., 2014), and 75% of telemedicine projects fail completely, with this percentage reaching 90% in developing countries (Bali, 2018).

The truth is although in telehealth pilot projects, benefits such as reduced referrals, increased access to services, reduced costs and improved communication in primary, secondary and tertiary referrals are promised, there is no guarantee that the transfer of the technology from the test phase to the practical phase and a large scale implementation should be accompanied by long-term success (LeRouge et al., 2010). For example, due to several challenges, telehealth start-ups struggle to meet conventional healthcare costs, and this impacts their commercialization (Chakraborty et al., 2023).

Moreover, despite the advantages of telehealth technology, its effectiveness is sometimes under question, as there may be a mismatch between the stated benefits or the value proposition and the actual results obtained. As a result, healthcare professionals might be reluctant to use this technology. In fact, they might be skeptical about its benefits (Bashshur et al., 2011). Age, level of education and computer literacy of patients can also affect the amount of technology use (Cottrell & Russell, 2020). The lack of individuals awareness, inadequate software and hardware infrastructure, insufficient budget allocation, the willingness of physicians and patients to be visited in person, insufficient budget for research, and concerns over privacy protection are other challenges for the large-scale implementation of this technology (Ahmadi et al., 2018; Masjedi et al., 2013). In addition to the above, aspects such as technical, legal, change management and financial issues can also affect the success or failure of this technology (Van Dyk, 2014; Valenta et al., 2021).

Thomas et al. (2022) highlighted five key requirements for the long-term sustainability of telehealth services. These included developing a skilled workforce, empowering consumers, reforming funding, improving the digital ecosystems, and integrating telehealth into routine care. Some of the key factors that contribute to the success or failure of a telehealth business are described below.

Infrastructures needed to implement telehealth

For the successful implementation and optimal use of telehealth technology, the necessary infrastructure, such as the high-speed Internet, computer hardware, updated software, and the systems required for video-conferencing must be available (Combi et al., 2016; Gorski et al., 2016; Pereira, 2017). However, there is a variation in technology infrastructure across countries and within countries (Thomas et al., 2022). One of the main requirements is the network bandwidth which seriously affects the quality of communication. For example, using a low bandwidth, only textual and simple data are transferred, but using a high bandwidth, it is possible to transfer more complex information, including voice, static images, dynamic images, and videos. Therefore, a wider bandwidth is required to send information in synchronous communication compared to sending information in asynchronous communication (Combi et al., 2016). One of the key requirements for televisit, especially when video-conferencing is necessary, is access to high-speed Internet with a suitable bandwidth (Mahtta et al., 2021).

In addition to the initial investment for proper technical infrastructure, continuous technical support is also necessary. Since IT service platforms are constantly evolving and provide different competitive advantages, deciding about appropriate service platforms is a strategic decision (Pereira, 2017). Sometimes the sudden failure of a project can be due to poor Internet access and limitations in feeding devices, storage, or message transmission mechanisms (Gorski et al., 2016).

Responsibility for providing telehealth services and ethico-legal issues

When healthcare services are provided in a traditional way, it is easy to track the relationships between patients and service providers. However, in telehealth services, there is always a healthcare provider who might be in a remote area or in another country (Saei & Saghafi, 2014). Therefore, many service providers and patients are concerned about the responsibility of providing telehealth services (Becevic et al., 2020; Cusack et al., 2008). In fact, it is unclear whether the service provider is the one who is responsible for visiting and treating the patient, or anyone who provides health advice (Cusack et al., 2008). Moreover, sometimes telehealth service providers work in a healthcare center, and direct responsibilities, such as equipment defects or communication interruption and indirect responsibilities like clinical staff malpractices should be clearly defined by legislators (Bali, 2018; Cusack et al., 2008; Saei & Saghafi, 2014).

Similar to in-person healthcare services, the possibility of getting access to the patient's information, such as medical records, information about the type of illness and the recovery process should be defined for telehealth services, and it is mandatory to comply with the rules set for maintaining the confidentiality of patient data. Otherwise, both patients and healthcare providers will be reluctant to use the technology (Saei & Saghafi, 2014). The lack of data confidentiality and privacy policies may lead to unintended violation of patient rights. In addition to the understandable data confidentiality and privacy policies for patients and healthcare providers, technical solutions need to be in place to reduce security risks (Mahtta et al., 2021).

Reimbursement of telehealth services

While telehealth policies continue to improve, reimbursement is often cited as a major challenge to telehealth adoption (Valenta et al., 2021). In fact, payment for telehealth services is a factor that can affect the success or failure of telehealth businesses (Smith et al., 2020). One of the biggest obstacles to the implementation of telehealth technologies is the lack of clear rules regarding the reimbursement to the organizations and physicians who use these technologies (Wanner et al., 2010). In one-fourth of the world's countries in which telehealth is being used, the dominant financial strategy is based on reimbursement plans (Grustam et al., 2017b). However, inadequate reimbursements can slow down the technology adoption process (Black et al., 2011; Pirtle et al., 2019; van Gemert-Pijnen et al., 2011). For example, in the United States, limitations on reimbursements have affected the widespread use of telehealth, and although reimbursement rules are evolving and being refined, the current payments account for a small proportion of total healthcare expenditure (Mahar et al., 2018). For example, payers such as insurers do not consider home care to be the primary site of healthcare (Dinesen et al., 2016). Overall, the lack of transparency in the reimbursement laws may cause disparities in payments to healthcare providers, and a clear legal framework with supportive strategies is needed to solve the reimbursement problems (Marcoux & Vogenberg, 2016). In addition, current reimbursement models should be modified by policymakers and payers, and different stakeholders should be encouraged to adopt telehealth services (Cusack et al., 2008).

Rules, standards, and license for telehealth services

Two major legal challenges for providing telehealth services are information security in telehealth platforms, and getting required licenses to use telehealth technology at the state, country, or international levels (Wijesooriya et al., 2020). For example, in the United States, the provision of telehealth services requires different licenses, and licensing laws have some limitations for providing these services (Cusack et al., 2008). In many states, physicians require state licenses, and in more than one state, they need to apply for multiple licenses (Cusack et al., 2008; Mahar et al., 2018).

In addition, the adoption of standards helps to establish easy communication between different healthcare centers that are responsible for providing telehealth services. Although standards increase data security during information sharing (Combi et al., 2016), it is necessary to update them (Wijesooriya et al., 2020). Similarly, telehealth services should be evaluated, validated and approved by responsible organizations and regulatory bodies to ensure that they comply with relevant laws and regulations (Combi et al., 2016).

Cooperation with different stakeholders

Telehealth services are quite complex and include a combination of information technology-based and person-oriented services with multiple stakeholders (Peters et al., 2015). A stakeholder is someone who affects or is affected by a project or business (van Limburg et al., 2011). Since there are different stakeholders in a business, their requirements need to be met (Leeuwerden, 2018). Stakeholders are very diverse and at different levels include the government, healthcare professionals, and patients (Bali, 2018; Bourdon et al., 2018), The degree of their importance is defined based on the three variables of power, legitimacy, and urgency, and the most important stakeholder has a greater impact on the business (van Limburg et al., 2011). As the implementation of telehealth services at a large scale may last several weeks or months, continuous stakeholder engagement is needed to properly deliver the value proposition (Peters et al., 2015).

In a telehealth business, the interaction with the stakeholders is sometimes very difficult, as the precise definition of the technology goals, users, timely allocation of resources, leaders' decisions and responsibilities are not often clearly defined. Therefore, specific policies need to be taken into account to cooperate with the stakeholders (Bali, 2018; van Gemert-Pijnen et al., 2011).

Organizational factors

The provision of telehealth services usually involves more than one organization, and these organizations often have different cultures and structures that influence implementation processes (Van Dyk, 2014). In fact, differences in the methods of problem-solving and decision-making may add to the complexity of implementing telehealth services (Van Dyk, 2014). In addition, telehealth services need to be supported by different healthcare workers, information and communication technology experts, economists, managers, and policymakers. Therefore, poor management, insufficient staff training, and lack of motivation can hinder the success of businesses in their early stages (Gorski et al., 2016; Van Dyk, 2014). Factors such as the methods of service delivery, agreement between hospitals and healthcare providers for service delivery, and the amount of cost saving or revenue making are among the organizational factors that can lead to the success or failure of a telehealth business (Fanale & Demaerschalk, 2012).

Economic factors

Economic challenges can be both internal (e.g., limited funding for telehealth initiatives and poor understanding or execution of effective telehealth business models) and external (e.g., the limited and variable telehealth reimbursement policies across the country) (Valenta et al., 2021).

Having adequate knowledge about economic factors affecting telehealth businesses and related financial models is essential for start-up businesses or companies (Arkwright et al., 2021).The financial models in this field are unique and components such as people (clinical service providers and patients), geography (rural or urban areas), type of services, reimbursement, type of technology, quality of services, and outcomes need to be considered (Molkizadeh et al., 2020). Therefore, conducting cost-effectiveness and cost-benefit analyses are necessary to ensure the quality of telehealth services (Cush, 2014). These services should be economically viable in the long term (Gorski et al., 2016), and to achieve the expected benefits, adequate investment is necessary.(Bourdon et al., 2018).

Willingness of clinical staff and patients to use telehealth services

Telehealth service development is challenging particularly when attempting to integrate telehealth services into the current healthcare system (Valenta et al., 2021). Studies have shown that the acceptance of telehealth services by clinicians and patients is one of the most important factors influencing the success or failure of this technology (Wanner et al., 2010). User acceptance depends on factors such as the effectiveness, safety and naturalness of these services, and users need training to learn how to use the technology (Smith et al., 2020). In addition, change management strategies need to be in place to support clinicians with limited experience in using telehealth technology (Smith et al., 2020). In fact, clinicians may reduce using telehealth services, because of lacking prior training and not being ready to adopt telehealth in their clinical practice. Therefore, both current and future health workers should be trained in using digital health technology (Thomas et al., 2022). Convincing patients who prefer to meet their healthcare provider in person to change their routines and accept remote services is another cultural issue which should be considered in telehealth businesses (Wanner et al., 2010).

Commercialization of telehealth projects

Commercialization of an innovation refers to the activities required to introduce an innovation to the market (Datta et al., 2013). However, only one out of every 3000 new innovative ideas is commercialized. Therefore, it is clear that generating ideas is not enough to commercialize innovations (Datta et al., 2013). In addition, technology commercialization processes are complex and challenging, because in the modern business environment, customers need to see changes rapidly, and the technology life cycle is short (Pellikka & Malinen, 2014).

One of the main issues related to telehealth products commercialization is presenting their values (Cusack et al., 2008). However, the type of value, the methods of value creation and value presentation are different in developed countries and developing countries (Chen et al., 2013; Gorski et al., 2016). For example, in developing countries, the value of mHealth projects is reducing healthcare costs or increasing the effectiveness of healthcare services, especially in deprived areas (Chen et al., 2013). In the United States, Gorski et al. examined the business models used for 234 mHealth projects to identify their value propositions. The results of this study showed nine different value propositions in mHealth technologies (Gorski et al., 2016). These values included faster and easier access to medical care, adherence to drug treatment regimens, educational programmes, payment for medical care, patient healthcare data collection and storage (electronic medical records), reduction or avoidance of stigma, empowering government and medical professionals, increasing institutional efficiency, and quality control of care (Gorski et al., 2016).

In some countries, value means selling anonymized patient data to generate public health policies or create new products. The anonymized patient data include symptoms, treatment, quality of life, etc. which might be sold to the research companies (Chen et al., 2013). The alignment between the value and the technology is another important issue in telehealth businesses. Fanale and Demaerschalk conducted a study on the application of telestroke technology using a smartphone device to display diagnostic images and treat stroke. The results showed that the value proposition of the technology was low compared to the equipment and the allocated costs, and might have led to apathy and unwillingness of users to use the technology (Fanale & Demaerschalk, 2012).

It seems that for the sustainability of telehealth services, especially mHealth technologies, value creation should be prioritized instead of relying too much on external financial resources for investment. In fact, value creation is one of the essential components for sustainable investments in telehealth services (Gorski et al., 2016). It should be noted that telehealth is a multidimensional concept and its success depends upon several factors such as users, the conditions in which it is used, software, technology configuration and user interface, organizational structures and the combination of resources. When telehealth is regarded as a puzzle, all of these factors need to be considered as different pieces of a puzzle, and the right or wrong placement of each piece may have a direct impact on cost, quality of care, and access to care. In addition, these factors, which can be included in a business model, are useful for conducting research, policymaking, reimbursement decisions, and legislation (Bashshur et al., 2011).

Notably, most telehealth services seem to be vulnerable to failure, because they lack a proper business model, and many of these services end up only as a "successful pilot project" (Sprenger & Mettler, 2016). In fact, along with technological innovations, the use of a business model is important to guide business performance and helps with revenue making (Haaker et al., 2017; Meertens et al., 2012).

Business model

Over the past two decades, the use of business models has been expanded in theory and practice as a concept for the sustainability of enterprises and companies

(Stott et al., 2016; Zhao et al., 2020). A business model explains how a company creates and captures value in coordination with business partners, customers and suppliers. It also specifies the business model for the business partners, determines the value offered to the business partners, and covers the business and its complex activities as a whole (Zhao et al., 2020). This model answers the basic questions that every manager should ask. Some of the questions are how to make money from this business and how to deliver value to the customer at a reasonable cost (Effertz et al., 2017). The business model can be defined as architecture for the commercialization of a product, service, and information. Also, the business model can include financial resources, contributors and stakeholders, their roles, and competitive product benefits (Oderanti & Li, 2016).

In the business model of innovative products, the value component must support value creation for the entire community, such as patients, healthcare providers, and policymakers (Fusco & Turchetti, 2015). In addition, the potential economic value of a new product and technology is predictable using the business model (Pellikka & Malinen, 2014). In fact, the idea behind the business model is a simple and abstract view of the performance of a company according to its necessary components (Kimble, 2015). It should be noted that business models are applicable for different purposes (Marjomaa, 2015) and support business sustainability. Sustainability here means emphasizing the desire to survive over time and create a successful and profitable institution in the long term. Sustainability also means the ability to remain competitive (Nielsen & Lund, 2014), and competitiveness involves a set of factors, institutions and policies that describe the productivity and capacity to improve the income level and well-being of individuals in a society (Saigí et al., 2016). The companies that have been financially successful are more concerned about using a sustainable business model (Wirtz et al., 2016).

Business models have components that seem to affect the survival of a start-up business or company, and knowing the structure of these models and their impact on the business functions can increase the likelihood of the business's survival (Slávik, 2019). In some studies, business models refer to intangible assets of businesses and companies, and if a simple idea has strong and profitable business model support, it is more valuable than an idea that has no profit-making business model to support (Hanafizadeh et al., 2015). It should be noted that a business model cannot be a static way of managing a business, and must be continuously revised and optimized to be able to meet the competitive atmosphere requirements (Nielsen & Lund, 2014). In fact, the business model must be dynamic and due to changes in the market, technology and regulatory environments must constantly change from the R&D stage to the establishment (Kijl et al., 2010). Hence, it seems necessary to revise business models to keep companies and businesses competitive (Ranjith, 2016). Obviously, successful business models cannot be created just based on a sudden decision and are the result of an evolutionary process (Acheampong & Vimarlund, 2015; Fachinger & Schöpke, 2014).

Different approaches in applying business models

The literature review shows that business models have been examined by various researchers from different disciplines ranging from information systems and management to computer science, and a variety of definitions and components have been proposed for these models (Acheampong & Vimarlund, 2015; Fachinger & Schöpke, 2014; Haaker et al., 2017). The common terms related to business models are business strategy, business idea, business plan, business concept, revenue model, market model, and economic model, and sometimes these concepts are used interchangeably (Pereira, 2017; Türko, 2016; Wirtz et al., 2016). However, each of these terms may have different definitions. For example, a business model is a direct result of a business strategy, but it is not a strategy by itself. A strategy includes a vision that simply tells which direction the idea will go in the future and how the underlying decisions about the medium and long-term goals will be made (Wirtz et al., 2016). The business idea includes the entrepreneurial goals, while the business model represents a more formal conceptualization and reflects the durability of the business idea. A business plan provides a formal description of the business in future and is broader than the value proposition. In fact, the business plan includes more minor issues such as cash flow, strategic plans for short-term goals, capital structure, costs, etc (Türko, 2016).

A business model represents the logic of creating the value of a company or business with a comprehensive description of the activities in a cumulative manner and provides a tool for a coherent implementation of a business strategy. Therefore, a business model works as a bridge between the future planning (strategy) and the practical implementation (process management) (Wirtz et al., 2016). To increase the competitive advantage of a business model, it should be reviewed regularly and aligned with the strategy (Stott et al., 2016). Zot et al. identified three distinct concepts of business models after reviewing 103 articles from 1975 to 2009. These concepts described a business model as a premodel (for e-commerce), a business model as a flow of activity (for strategic analysis of network activities) and a business model as a cost structure/revenue source (for economic analysis) (Chen et al., 2013; Zott et al., 2011).

There are three different approaches to using business models. These are economic, operational and strategic approaches and each of them contains a unique set of variables for decision making. In the economic approach, the focus is on how the companies are profitable. In this approach, the key components of the business model include pricing methods and strategies, revenue sources, cost structures, profits and sale levels. This approach represents the current profitability of the firm and predicts the future sustainable income (Pereira, 2017). The operational approach examines the company's operational processes, or internal processes to create interdependent companies that can sustain their competitiveness in the market. In this approach, the focus is on dealing with the core components of the business model, which include production, implementation of the projects, process management and knowledge management (Pereira, 2017). The strategic approach emphasizes the marketing position of the company, the growth prospects and opportunities as well as organizational and institutional interactions. Therefore, the focus is on how companies define different customers, products, services, customer value propositions and outsourcing processes to ultimately make a profit (Pereira, 2017). In general, the use of business models provides managers with a systematic and experiment-oriented approach to test their options in uncertain and unpredictable situations (Haaker et al., 2017).

Business model components

Business models are often expressed with a variety of components (Wirtz et al., 2016), and sometimes understanding these components is challenging (Weidner & Lowman, 2020). Business modeling is more like an art than a science because there is no unique way to select components of business models (Meertens et al., 2012). A business model defines the key components for the successful implementation of a business idea. As a practical concept, models can be described in terms of a combination of company beliefs, products or services, key stakeholders, costs and profit (Weinstein et al., 2014). Therefore, many components can be considered for a business model (Shafer et al., 2005; Wirtz et al., 2016). Also, business strategy has a great impact on the development of a business model and can act as a guide (Wirtz et al., 2016). One of the most important components of business models is value (Chen et al., 2013). In fact, a business model is a conceptual framework for value creation and profitability, and a company's pricing strategy and revenue model determine to what extent value creation has been profitable (Effertz et al., 2017; Stott et al., 2016; Wirtz et al., 2016). In addition to the general concepts of business strategy, external factors such as customers, market, and many other internal factors may affect value creation and should be considered (Effertz et al., 2017; Wirtz et al., 2016).

In a study conducted by Shafer et al., the definitions of business models were examined and four components, namely, value creation, value acquisition, value network and strategic options were identified (Shafer et al., 2005). Moreover, stakeholders' opinions about the type and amount of value that a business creates vary and should be considered in a business (Lehoux et al., 2014). Business models also present a description of an organization or a network of organizations that intend to create and capture value through the provision of products and services (Haaker et al., 2017). A network-based perspective can be considered as one of the components of the business models. In fact, networks and partnerships have a huge impact on value creation and should be considered as an important component of the business models. Other components include customers and their roles (Wirtz et al., 2016). The market offering a revenue model can also be considered an important component. In fact, the revenue structure and revenue stream should be designed to maximize revenue and the revenue model supports the total revenue stream of the business (Wirtz et al., 2016).

The financial model is another component of a business model which is important for careful financial planning, capital frictionless flow, and analyzing the cost structure (Wirtz et al., 2016). Overall, it can be said that business models might be different in terms of the scope and fundamental components such as customer, value proposition and the way revenue is generated (Haaker et al., 2017). In some models, a limited number of components are considered, while others are more comprehensive (Wirtz et al., 2016). The components of a business model must be coherent and existing facilities must be able to provide the expected value. The business model must also match the internal structure of the company (Teece, 2018).

Different types of business models

Two business-to-business (B2B) and business-to-consumer (B2C) models are among the most common models used in businesses (Kumar & Raheja, 2012). The B2B model is a type of strategy in which a business or a legal personality has a commercial transaction with another business or legal personality (Grustam et al., 2017a). It also refers to trade between businesses such as manufacturers, wholesalers, and retailers (Kumar & Raheja, 2012). An alternative option introduced for the B2B model is the B2C model. In this model, the strategy is based on a business transaction with the customers and consumers (Grustam et al., 2017a). In fact, the consumer seeks to receive the goods or services and lower prices are offered by removing the intermediaries (Deshmukh, 2020).

Another key influencer in the business environment is a government that has developed new business models based on their interactions with businesses and consumers (Deshmukh, 2020). Some of these models are described below:

- The government-to-government (G2G) model involves trade exchanges between two governments or two government agencies.
- The government-to-consumer (G2C) model includes exchanges between the government and the consumers.
- The consumer-to-government (C2G) model involves exchanges between a consumer (a real person) and the government (Deshmukh, 2020).
- The government-to-business (G2B) model involves exchanges between the government and a business or legal entity.
- The business-to-government (B2G) model involves exchanges between a business or legal entity and the government (Deshmukh, 2020).

Osterwalder's business model canvas

In 2004, Osterwalder provided a broad definition of the business model. According to this definition, a business model is a conceptual tool and includes a set of components

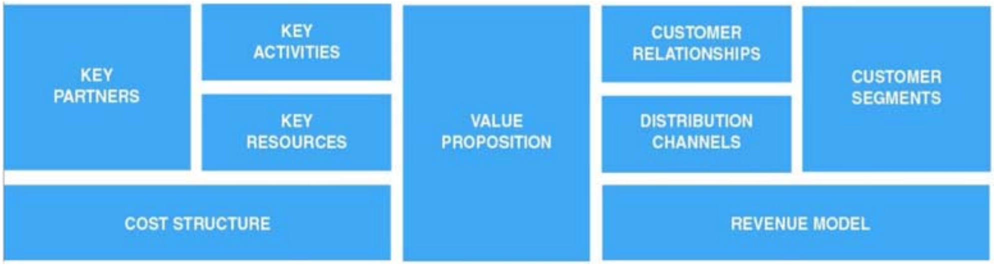

Figure 19.1 Osterwalder's business model canvas (van Limburg et al., 2011).

and relationships that demonstrate the company's logic for earning money. It is also a description of the value that is presented to the customer. This model describes the architecture of the company and the network of partners to create a market and transfer value with the appropriate capital so that a profitable and sustainable revenue stream can be achieved (Pourabdollahian & Copani, 2014). In addition, Osterwalder and Pigneur proposed a tool for defining the business model canvas which is still used in many businesses (Fig. 19.1) (Pourabdollahian & Copani, 2014; van Limburg et al., 2011).

The business model canvas consists of four main perspectives, not components (Chen et al., 2013). Its four perspectives are infrastructure (including key partners, key activities, and key resources), value proposition, customer issues (including communication with customers, distribution channels, and customer segments), and financial issues (including cost structure and revenue model) (Chen et al., 2013; Ju et al., 2016; Stott et al., 2016). The Osterwalder business model canvas is a model for developing new business models or documenting existing models (Kimble, 2015). This model is one of the most widely accepted business models, which has been widely used as a formal tool for different product commercialization including technology (Marjomaa, 2015). It focuses on strategic and operational management issues (Nikou & Bouwman, 2017), and is a predominantly used model in the field of telehealth technology (Chakraborty et al., 2023).

This model is often seen as a brainstorming tool for defining marketing strategies, but its major drawbacks are the lack of sufficient emphasis on the importance of the digital economy and the functionalities of core enabling technologies (Nikou & Bouwman, 2017). This business model cannot manage multipurpose service platforms and requires the application of different business models in parallel (Nikou & Bouwman, 2017). In addition, it is more product-oriented, and the network and nature of the key partners in businesses have not been addressed adequately (Marjomaa, 2015).

Ash Maurya's lean canvas

Maurya's lean canvas was adapted from the Osterwalder business model canvas. This model contains some components to identify the problem and its solutions for start-up

Figure 19.2 Ash Maurya's lean canvas (Ash, 2012; York, 2020).

businesses and companies. This model is mostly used when a business starts to work and sometimes is used in combination with the Osterwalder model. The model has nine components, of which five components are almost identical to the components of the Osterwalder model, and the other four components include the problem, the solution, key metrics and competitive advantages (Fig. 19.2) (Ash, 2012; York, 2020).

The STOF business model

Another business model is the STOF model, which focuses on "Service, Technology, Organizational, and Financial areas" (Fig. 19.3). The service covers general issues and plays an important role in conceptualizing services such as creating values for the customer (Leunissen, 2008). It also focuses on the value offered by the provider and describes the offered value, the expected value and the perceived value (Marjomaa, 2015). The technology covers the requirements and technical architecture (Leunissen, 2008), infrastructure, networks, operating systems, devices, applications, data and technical performance (Marjomaa, 2015). The organizational domain covers the organizational structure necessary for the establishment of the service and includes the financial issues and pricing (Leunissen, 2008). The financial issues include profits, investments, costs, risks, and sources of income (Leunissen, 2008; Marjomaa, 2015).

The STOF business model is a map of the services that will be provided. In this model, the intended services and values for the target group, income resources and

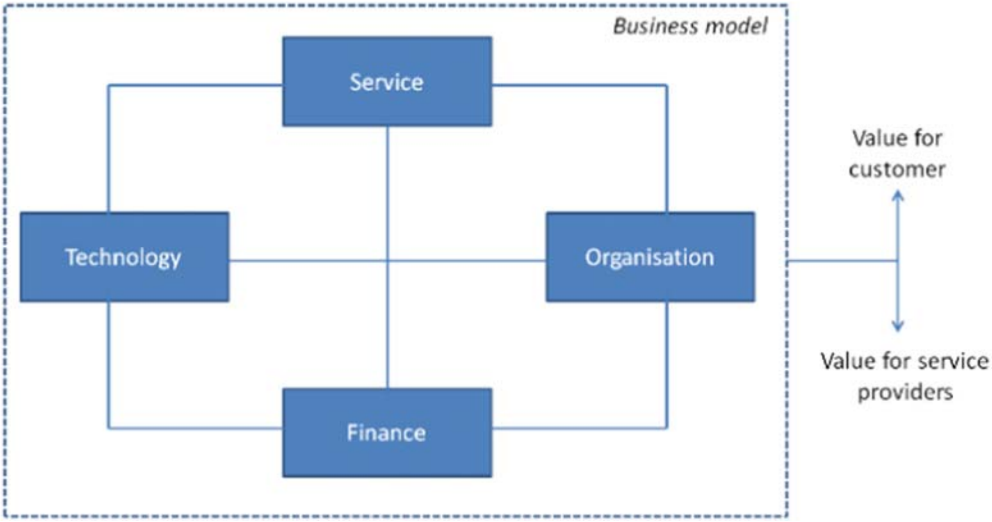

Figure 19.3 STOF business model (Marjomaa, 2015).

architecture for service delivery which includes a description of the roles and shares of costs and revenues between stakeholders are presented (Leunissen, 2008; Spil & Kijl, 2009). The model lists a set of predefined variables and describes the success factors for the business models (Nikou & Bouwman, 2017). This business model is mostly based on services (Marjomaa, 2015).

Using business models in telehealth businesses

When implementing and commercializing telehealth technologies, we must ensure that technology sustains in the real-world situations and conditions. Therefore, all of the involved organizations must cooperate and interact from the onset. In addition, some organizations must support businesses or be able to finance them. However, telehealth technologies are complex and need to fit with the existing care processes. In other words, technology development is beyond the technical design due to the complexity of the health systems, and more research is needed to determine what the successful implementation and commercialization strategies are (Marjomaa, 2015; van Limburg et al., 2011).

The Center for eHealth Research and Disease Management (CeHRes) Roadmap developed a comprehensive framework for improving the acceptance of electronic health technologies (van Gemert-Pijnen et al., 2011; van Limburg et al., 2011). In this center, developing telehealth technologies and business modeling are considered interrelated activities. Therefore, technologies are designed based on the users' requirements and the development process is value-driven. In addition, stakeholders are involved in the development process to be able to implement telehealth technologies based on the values (van Limburg et al., 2011).

In a successful business model for telehealth technology, financial variables are also taken into account (Arkwright et al., 2021). In 2019, Arkwright et al. defined financial variables and business models for telehealth services. They found that telehealth financial variables included fee-for-service payments, value-based payments, per member per month or per patient per month payment, coinsurance, shared savings, facility fees, and extramural funding (Arkwright et al., 2021). It should be noted that the field of healthcare is evolving and requires highly flexible business models to be quickly adapted to the new trends in the market (Pourabdollahian & Copani, 2014).

When developing business models for the healthcare industry, different types of laws need to be taken into account (Pourabdollahian & Copani, 2014). For example, patient data, medical history and physical condition, and other sensitive data should be considered confidential and treated according to the data protection laws. Patients should be informed that their data are collected, used, or sent to a third party (Ateriya et al., 2018).

It is notable that advanced technology cannot guarantee success in the market, and new technologies need to follow good business models to survive in the market (Lin et al., 2010). In other words, one of the main reasons for the technology business failure is the lack of appropriate business models (Meertens et al., 2012). In fact, the economic value of a technology can be obtained when it is commercialized through a business model (Marjomaa, 2015; Oderanti & Li, 2016). The use of comprehensive business models and frameworks for telehealth technology can play a pivotal role in reducing additional risks and costs and increasing their chances of success (Chen et al., 2013). According to the literature, there are two well-known business models developed for telemedicine technology. These models are discussed below in detail.

The VISOR business model

The VISOR business model was primarily introduced for mHealth services in 2008, and then, for telehealth technology in 2017 (Fig. 19.4) (Fife & Sawcer, 2008; Pereira, 2017) According to the VISOR model, a successful business model must have the highest proposed value to maximize the willingness of consumers to pay for that. This model includes five components which are the value proposition (V), the interface (I), the service platform (S), the organizing model (O), and the revenue model (R) (Fife & Sawcer, 2008; Pereira, 2017). The value component explains why the customer is willing to pay for the product or service. Indeed, the willingness to pay for a product or service indicates that the product meets the end-user's requirements. The interface refers to the ease of use and simplicity of using the product or services (Fife & Sawcer, 2008; Pereira, 2017). The service platform is related to the operating systems that

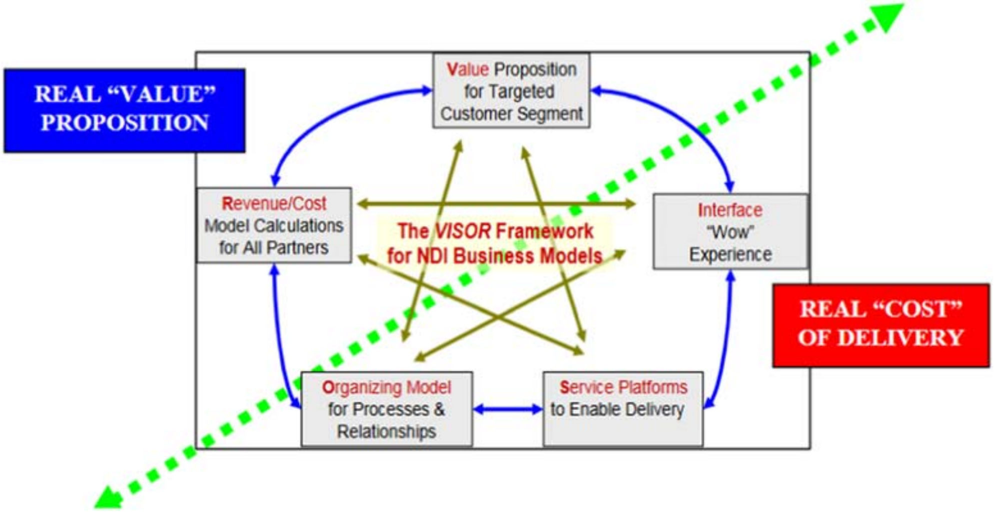

Figure 19.4 The VISOR business model (Fife & Sawcer, 2008; Pereira, 2017).

support business processes, relationships, and products, and improves value proposition. The organizing model determines how a company or a set of partners are organized in business processes and value chains, and how the partners' relationships are structured to effectively deliver products and services. The revenue model is a combination of value, proposals and investments in the context of technology. In a good business model, the revenue must outweigh the costs and be attractive to all partners (Fife & Sawcer, 2008; Pereira, 2017).

Each component of the VISOR business model consists of several subcomponents. The analysis of this model shows the interaction between the components of the business model. In this business model, weakness in one component can be compensated by stronger aspects in other components. For example, if the value component for a digital product or service is weak, it can be compensated by the stronger component which might be the organizing model to continue providing the value (products and services). By contrast, a strong value component can compensate for weaknesses in the interface or service platform during the product or service delivery (Pereira, 2017).

The CompBizMod framework

The complex services business model (CompBizMod) framework was presented by Peters et al. to explain the four basic features of the business models in the field of telemedicine. The main dimensions of this framework are value proposition, value co-creation, value communication and transfer, and value capture. This framework is in the form of a morphological box that consists of dimensions with multiple

Dimension	Parameter	Characteristic			
Value Proposition	Overall purpose	Prevention	Diagnosis	Therapy, curative	Therapy, palliative
	End consumer	Professional provider, physician (B2B)	Patient, relatives (B2C)		
	Partner network	A fixed set of other partners is involved	A flexible, competing set of partners is involved	No partners are involved, or if at all indirectly	
	Realization of benefits for the patient	By application	(if at all) indirectly		
Value Co-Creation	Portfolio role	One of several offerings in the same area	Complement offering	Singular, stand-alone offering	
	Contact with patient	Direct	Indirect	No	
	Domain-specific know-how	Not necessary	Necessary, provided by own employees / in-house	Necessary, requires cooperation with (external) domain experts	
	Required responsiveness	Immediate personal reaction	Automated immediate info forwarding, non-immediate personal reaction	Non-critical	
Value Communication & Transfer	Required means of communication*	No*	Platform (server, database)*	Measuring devices / wearables & platform*	
Value Capture	Type of revenue	Transaction-based	Transaction-independent	Mixed	
	Paying entity	Health insurance	Patient	Other stakeholder	Mixed
	Cost drivers	Personnel costs	Equipment		

Figure 19.5 The CompBizMod framework (Peters et al., 2015).

characteristics and features, and for each business model, only one feature can be selected in each characteristic to create a clear distinction between different business models (Fig. 19.5) (Peters et al., 2015).

The 4P telehealth business framework for Iran: a case study

Despite the successful experiences in providing telehealth services in many countries, the start of these activities in Iran has faced challenges such as patients' and clinicians' resistance to change, inadequate funds to set up the telehealth systems (Masjedi et al., 2013), insufficient knowledge of clinical staff, a lack of required facilities, equipment, expertise, and a lack of coordination between the stakeholders (Doshmangir et al., 2015; Ghasemi Ravari et al., 2016). In addition, insurance and reimbursement issues and initial infrastructure costs have been reported as the most basic obstacles to running a telehealth business in Iran (Ghasemi Ravari et al., 2016). Considering the context of a country like Iran which can be different from other countries in terms of organizational, insurance, infrastructural, economic, and cultural issues, it seems that the components affecting the telehealth businesses are also different, and might be more than the existing ones reported in the current business models and frameworks. Therefore, proposing a new framework for telehealth businesses can be useful to gain a better understanding of the influential components, and for commercialization of telehealth products and services.

This study aimed to create a framework for telehealth businesses in Iran, and was conducted in 2021 using a mixed-methods approach which included four phases. The first phase included a systematic review in which the telehealth business models and

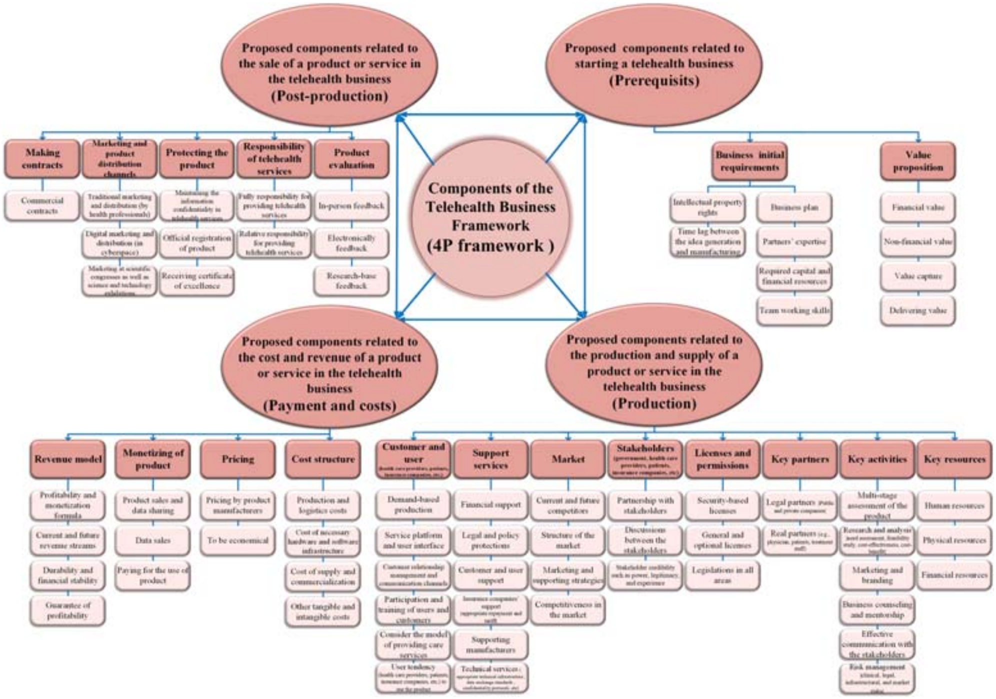

Figure 19.6 The 4P telehealth business framework (Velayati et al., 2022).

frameworks were identified and reviewed (Velayati et al., 2021b). In the second phase, people who were experts in the fields of medical informatics, health information management, health entrepreneurship, and telehealth business were interviewed to identify the main components of a telehealth business framework in Iran (Velayati et al., 2021a). Then, in the third phase of the study, a primary version of a telehealth business framework was created based on the findings derived from the first and second phases of the research. It was presented in an expert panel and the experts' comments were used to refine the framework. Finally, the proposed framework was validated using the Delphi technique (three rounds) (Velayati et al., 2022).

The final framework included four main dimensions: telehealth business prerequisites, production, payments and costs, and postproduction services. Each dimension is composed of a number of components necessary for developing a telehealth business plan. In total, 68 components were considered in four dimensions. The final framework was named "the 4P telehealth business framework," as all dimensions started with the "P" letter (Fig. 19.6) (Velayati et al., 2022).

This framework can be used as a conceptual tool to demonstrate how innovation, technology, and associated knowledge can be profitable through the commercialization process (Velayati et al., 2022). Compared to the previous telehealth/telemedicine business models and frameworks, such as the VISOR business model (Fife & Sawcer, 2008) and the CompBizMod framework (Peters et al., 2015) which have focused on a limited number of components, this study a number of organizational, technical, nontechnical, and financial, components were considered to present a more comprehensive picture of the influencing components in a telehealth business (Velayati et al., 2022). The proposed framework can support the telehealth innovators for their commercialization plans in Iran and in any country with a similar context. In addition, policymakers can encourage telehealth start-ups to consider the components of the framework in order to fill accessibility, affordability, quality, and equity gaps (Chakraborty et al., 2023).

Overall, the results showed that multiple dimensions and components may have a direct or indirect impact on a telehealth business. The weight of these components can be examined in a real telehealth business, and the proposed framework can be a basis for further research in this field (Velayati et al., 2022). In addition, due to the differences in the health systems, values and legal issues in each country, it seems that the components affecting the telehealth businesses are different and need to be explored separately.

Conclusion

As telehealth technology is a multidimensional concept, its beneficial use depends on different factors, such as stakeholders and their interests, conditions in which the technology is used, type of software, technology configuration, etc. Therefore, a telehealth business model/framework and its components can be used to ensure that all necessary aspects have been considered. Telehealth business models and frameworks can also play an important role in the successful implementation and commercialization of ideas and technologies. However, their potential has not fully realized yet. Business models and frameworks consist of a set of interrelated components that facilitate the process of creating value from ideas in the form of a business. In this chapter, the concepts of telehealth commercialization and different types of business models were reviewed. In addition, the results of an empirical study in Iran showed that the components needed to design business models and frameworks for telehealth technology vary and due to the diversity of technologies, health systems, cultures, values, objectives and applications different components should be considered.

The proposed framework can be used as a guideline for start-ups and governments to control as many influential factors as possible to implement large-scale telehealth services for all citizens. Not only in Iran but also in other countries, particularly those that are in Asia with similar contexts and cultures, the framework can be used to invest in and implement future telehealth platforms. However, the effectiveness of the business models and frameworks should be examined in practice to show how they can help with telehealth commercialization.

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SECTION V

Trends and Implications for healthcare research agenda and policy

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CHAPTER 20

Healthcare transformed: a comprehensive survey of artificial intelligence trends in healthcare industries

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Introduction

Artificial intelligence (AI) is indeed making significant strides in the field of medical sciences transforming various aspects of healthcare. While there is great potential for AI to revolutionize healthcare, there are both opportunities and challenges to consider. AI is the development of an algorithm in machines which is similar to human intelligence. Deep learning (DL) is more efficient in the prediction of results in various applications. It has some limitations which can be overcome by neuro-symbolic AI. Data inefficiency, lack of interpretability and poor generation are some of the problems faced by deep neural networks. The performance of DL is increased only with massive amount of data.

In certain cases of image processing especially in the medical field, it is not easy to get huge amounts of data and this limitation was overcome by Generative Adversarial networks (GANs). Images were artificially synthesized and combined with real images to increase the amount of data. It includes a Generator network and a Discriminator network.

The former produces the fake images by means of masking and the latter receives real images as well as fake images from Generator network. The probability distribution (PD) of real images is compared with the PD of fake images and it discriminates the fake images according to it. Many improvement made in GANs resulted in conditional GAN, super-resolution GANs that increased the texture details and more realistic images with sharper edges. The positive strength of DL is to find important features in high-dimensional data. Symbolic AI converts concepts into rules or symbols using a knowledge graph (KG). It is very difficult to integrate the two frameworks probability and logic. A very important motive is to fuse DL representation with expert knowledge. Mohammed et al. (2021) state that many researchers are making great progress in AI to enhance the machines with special ingredients to make the

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machines think like humans. The integration between symbolic and KG is an active research in AI which can be accomplished by neuro-symbolic AI.

AI has tremendous potential to transform healthcare. There are technical, ethical, and logistical challenges to overcome. The approach described by Padma Usha et al. (2020) of employing various fusion methods and introducing Graph Intelligence techniques for enhancing the structural similarity of fused images for brain tumor detection sounds like a promising technique in medical imaging analysis. The fusion of different imaging modalities and the use of sophisticated techniques, like Graph Intelligence, can improve the accuracy and specificity of brain tumor identification, potentially aiding in more effective diagnoses and treatment plans

Basu et al. (2020) have shown that collaborative efforts from researchers, healthcare professionals, policymakers, and technology experts are essential to harness the benefits of AI while ensuring patient safety, data privacy and equitable access to healthcare advancements.

AI's applications in medical sciences are diverse and impactful:

Diagnosis and treatment: AI systems can analyze medical images such as X-rays and magnetic resonance images (MRIs) to assist doctors in detecting diseases and abnormalities. They can also recommend treatment plans based on data from similar cases offering personalized options.

Drug discovery and development: ai algorithms can analyze vast amounts of biomedical data to identify potential drug candidates and predict their effectiveness. This accelerates drug development and reduces costs.

Patient management: aI-powered chatbots and virtual assistants can help patients with follow-up care, medication reminders, and health-related queries. This improves patient engagement and outcomes.

Remote monitoring: wearable devices and sensors equipped with ai capabilities can monitor patients' health remotely, enabling early detection of health issues and improving patient compliance.

Mental healthcare: ai-driven virtual humans can create a safe space for patients to discuss mental health concerns. This technology can aid in diagnosing and treating mental health conditions more effectively.

Data analysis: aI algorithms can analyze large datasets to identify patterns and trends that may be missed by humans. This aids in disease prediction, outbreak tracking, and resource allocation.

Telemedicine: AI-powered telemedicine platforms connect patients with healthcare professionals remotely, overcoming geographical barriers and improving access to care.

However, there are challenges to address:

Data quality and privacy: ai models require large and diverse datasets to train effectively. Ensuring the quality, diversity, and privacy of medical data is crucial.

Regulatory hurdles: Developing and deploying AI-powered medical solutions requires adherence to regulatory frameworks to ensure patient safety and data protection.

Interpretability: Many AI models are considered "black boxes," making it difficult for healthcare professionals to understand how they arrive at their decisions. Interpretability is vital for building trust.

Ethics and bias: biased data can lead to biased AI outcomes, impacting patient care. Ensuring AI systems are fair and ethical is paramount.

Integration with clinical workflow: ai solutions need to seamlessly integrate into existing clinical workflows rather than disrupt them.

Skills gap: there's a need to train healthcare professionals in understanding and utilizing AI tools effectively.

Reliability: AI systems need to be rigorously validated and tested to ensure their accuracy and reliability in real-world scenarios.

Artificial intelligence in healthcare industries

AI is being utilized to enhance diagnostics, treatment, research, and administrative tasks. AI algorithms have demonstrated the ability to analyze medical images such as X-rays, MRI scans, and computed tomography (CT) scans with high accuracy. AI-powered image analysis can assist radiologists in detecting anomalies, identifying patterns, and providing faster and more accurate diagnoses. It can analyze large amounts of patient data to detect patterns that might be indicative of diseases. This is particularly useful in early diagnosis and personalized treatment planning.

For example, AI algorithms can predict the likelihood of certain diseases based on a patient's medical history, genetics, and lifestyle factors. AI can accelerate the drug discovery process by analyzing massive datasets to identify potential drug candidates. Machine learning models can predict the properties of new compounds and simulate their interactions with biological systems, reducing the time and cost associated with traditional drug development.

AI-enabled devices can monitor patients' vital signs remotely and alert healthcare providers if any concerning changes occur. Telemedicine platforms also leverage AI to facilitate remote consultations between patients and healthcare professionals.

AI can also play an important role in predictive analysis. It can analyze historical patient data to predict disease outbreaks, patient admissions, and resource utilization. This helps healthcare facilities better allocate resources and plan for potential surges in demand. It plays a crucial role in analyzing vast amounts of genomic data to identify genetic markers associated with diseases. This information can aid in personalized medicine and targeted therapies.

Deep learning

DL has indeed revolutionized the field of AI by significantly enhancing a machine's ability to comprehend intricate data relationships and engage in reasoning. At its core, DL endeavors to extract valuable features from datasets characterized by high dimensions while simultaneously harnessing the power of reasoning.

Garnelo and Shanahan (2019) have shown that the fundamental objective of DL lies in the creation of models that possess the prowess to identify objects within raw data and subsequently discern their intricate relationships. This undertaking necessitates the acquisition of knowledge concerning how to effectively integrate these objects and relationships thereby enabling diverse and meaningful processing approaches. By accomplishing this, DL endeavors to unlock new dimensions of understanding and insight, akin to the cognitive processes observed in the human mind.

Deep learning in healthcare

Deep neural network is a subset of machine learning that requires a massive amount of data to get trained. It cannot perform well when the input data is completely different from the training data. It is used in healthcare for various applications shown in Fig. 20.1. In Medical Image Reconstruction, high-quality visual representations from signals are acquired by medical imaging devices such as CT or MRI scanners which generate images that are clinically useful even from low doses of radiation or fast acquisition scans. High-quality reconstruction is vital for accurate diagnoses and treatment planning. DL is used for

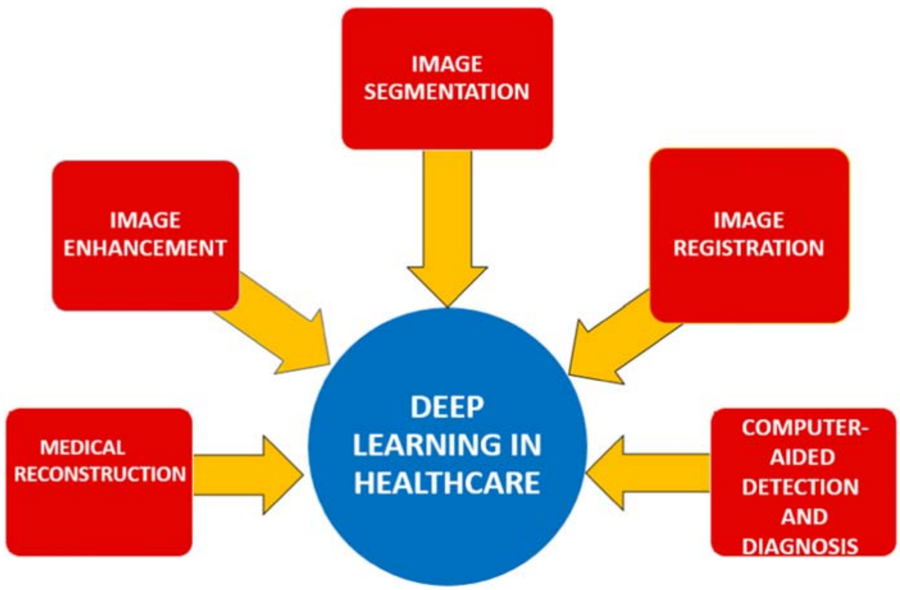

Figure 20.1 Application of deep learning in healthcare.

reconstructing the images. For **medical image enhancement**, the Image enhancement techniques improve the quality and suitability of medical images for display and analysis. **Denoising, super-resolution, bias field correction, and image harmonization** are methods used to enhance images making subtle details more visible and aiding in accurate interpretation. In **medical image segmentation**, labeling of each pixel in an image to group pixels with similar characteristics into meaningful objects or regions. This technology is crucial for quantification, therapy planning, and surgical interventions. Accurate segmentation facilitates precise measurements and targeted interventions. In **medical image registration**, images from different sources or time points into a common coordinate system. This is essential for comparing images, tracking changes over time and fusing information from multiple modalities. It's also used in conjunction with segmentation for label transfer. DL also plays a pivotal role in **computer-aided detection (CADe) and diagnosis (CADx)**. CADe involves automatically localizing objects of interest, often lesions, within medical images. CADx goes further by classifying the detected objects as benign or malignant or assigning specific lesion types. These technologies assist radiologists in identifying potential abnormalities, and reducing oversight errors. DL also plays a role in other technologies such as landmark detection focuses on identifying anatomical landmarks, aiding in accurate measurements and assessments. Image or view recognition involves automated recognition of specific views or image types. Automatic report generation streamlines the documentation process producing detailed and standardized reports.

In all of these technologies, the integration of AI and machine learning, particularly DL, has been instrumental in improving accuracy, efficiency, and automation. These advancements have significant implications for clinical practice, enabling more precise diagnoses, efficient workflows, and improved patient care. Additionally, as medical imaging continues to evolve, these technologies will play a crucial role in driving medical research and innovation forward.

Padma Usha et al. (2022) have demonstrated the utilization of multimodal image fusion in medical imaging, specifically merging MRI with CT, which offers a comprehensive insight into brain structures and potential pathologies such as tumors. In the context of brain tumor detection, this approach allows for a more holistic analysis of the tumor's characteristics, as different imaging methods provide distinct information about tissue properties and structures. The application of DL in the segmentation of the tumor region within these fused images demonstrates a powerful use of AI. DL techniques, particularly neural networks, are adept at learning intricate patterns within large and complex datasets.

Convolution neural network in image processing

Convolution neural network (CNN) uses DL algorithm which processes data similar to other networks using layers of convolution network. It includes a series of filters known as kernels or filters which are applied to the input image thereby producing a feature map as output. CNN learns important features from images. The layer of pooling is introduced to reduce the spatial size of input as it uses a small amount of memory. It helps in reducing the number of parameters which makes training faster. Max pooling and average pooling are the two types of pooling used before a fully connected layer. The goal of taking features learned by the previous layers that help in making predictions is done by a fully connected layer. CNNs are mainly used to identify and classify images. Today, CNNs are used for generating content about the description of the image or identify images and classify an image. There are various architectures and among them are Lenet, which is the first architecture for handwritten digit recognition issues. It is known as the "Hello world" of DL. The vanishing gradient problem is one of the limitations of Lenet. Hence max pooling is used between convolution layers to reduce the spatial size of images which prevents once filtering and allows CNN to transmit more effectively. AlexNet brought boom in CNN. The architecture of AlexNet was deeper, bigger and designed to be used with large-scale image datasets. It contains three fully connected layers along with max pooling. The activation used here is RELU and Softmax. Googlenet architecture has won the classification task where the error rate is reduced. CNN is computationally efficient and serves as a major application in computer vision. Googlenet is followed by Resnet, MobileNets and many other versions depending on the applications.

Symbolic artificial intelligence

A symbolic AI uses symbols to represent the real-world concepts. An arrangement is made in such a way that informs the AI algorithm how the symbols are correlated with one another and an expert system is used for processing this information. An inference engine is responsible for applying the rules to the selected symbols. It also instructs the AI how to act accordingly for "if" and "then" conditions.

Neuro-symbolic artificial intelligence

Neuro-symbolic AI is an emerging field in AI research that aims to combine traditional rules-based AI methods with modern DL techniques. The neuro-symbolic models have shown promising capabilities in outperforming state-of-the-art DL models in areas like image and video reasoning. Moreover, they can achieve high accuracy even with limited training data compared to traditional models. However, due to the novelty of the field and the limited availability of published results, there is still a lack of comprehensive understanding of the performance characteristics of these models.

It is a subfield of AI which brings neural and symbolic traditions in AI. The term "neural" is derived from artificial neural networks and "symbolic" which are based on explicit symbol manipulation such as graph algorithms and natural language questions, symbol manipulation and knowledge reasoning. One of the major strengths is trainability from raw data and it is robust against faults. On the symbolic side, it should be able to retain high explainability and correctness in order to make ease of human expert knowledge in their design. Siyav and Jo (2021) stated in their paper that in the case of representation, the symbolic systems are explicit and in the neural system, the representations are made as weighted connections between neurons. Symbolism and connectionism are the two important concepts of neuro + symbolic AI.

The two approaches of neuro-symbolic AI mentioned by Sheth et al. (2023) are as follows:

1. Compression and Integration of Knowledge and Extraction;
2. Mapping to Symbolic Knowledge.

They encapsulate the diverse ways in which neuro-symbolic AI methodologies combine the strengths of neural networks and symbolic reasoning. By effectively integrating or extracting knowledge from both modalities, these methods aim to enhance the overall performance, interpretability, and explainability of AI systems across various applications and domains.

Symbolism

It is a methodology by which human knowledge in introduced into the computer codes. Symbols are the building blocks of cognition. Symbols are arranged in a hierarchical way and make the model understand the concept of how it is linked with others and the information is processed through an expert system. The inference engine which refers to the knowledge base selects the rules that need to be applied to the symbols. It works well with applications that have clear-cut goals.

Connectionism

This model is prevalent today. It works similarly to the human brain and it uses perceptron to work on a single neuron. Artificial neural network is one of the finest examples. Each one has hundreds of units called artificial neuron. They have a layered format with weights which are the adjustable parameters forming connections with the structure.

Huang (2022) states that every neuron has weights, transfer function and output. The transfer function can access multiple inputs and combine them into a single value. It works very well when there is more amount of training data. All medical applications make use of this connectionist algorithm.

Combining connectionism and symbolism

The advantages of connectionism and symbolism can be combined and the limitation of each concept will be overcome by properly integrating these two concepts. If both these ideas are integrated together into the model then the performance of the model can be increased in such a way that it can able to reason for the particular decision it has made finally as output.

Neural-symbolic integration

Wang et al. (2022) have mentioned the types of neuro- symbolic AI. They are as follows:

Type 1: Symbolic Neuro Symbolic

The Symbolic Neuro Symbolic version of Type 1 is shown in Fig. 20.2. Here symbols are given as inputs to the neural network. The input symbols are converted into vector embedding which is processed by neural models and the output is transferred to a symbolic category using softmax operation.

Type 2: Symbolic [Neuro]

The model of Symbolic [Neuro] is shown in Fig. 20.3. Here the symbolic reasoning system has built-in neural networks which are loosely coupled with one another.

Type 3: Neuro | Symbolic

The diagram depicted in Fig. 20.4 illustrates the structure of Neuro | Symbolic, a hybrid system that harmoniously combines neural and symbolic components to tackle complex tasks. The Neuro | Symbolic structure showcases the integration of neural network and symbolic reasoning functionalities in a harmonious manner. By harnessing the collaborative potential between these components, the hybrid system aims to provide a comprehensive and robust approach to problem-solving while maintaining interpretability and explainability.

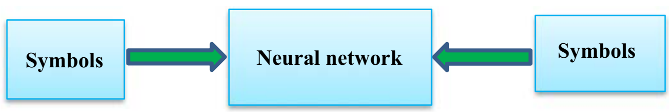

Figure 20.2 Type 1: Symbolic Neuro Symbolic.

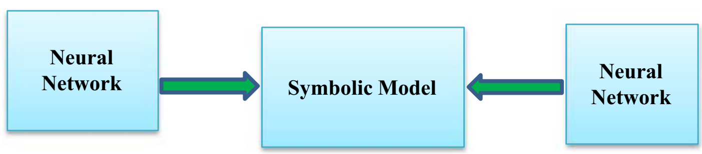

Figure 20.3 Type 2: Symbolic [Neuro].

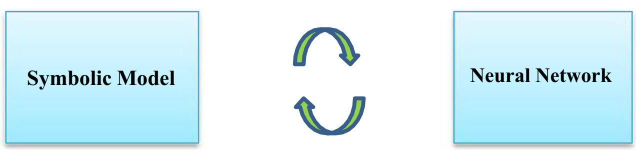

Figure 20.4 Type 3: Neuro | Symbolic.

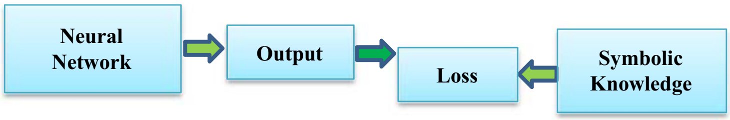

Figure 20.5 Type 4: NeuroSymbolic.

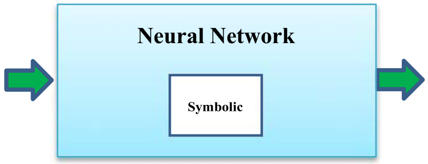

Figure 20.6 Type 5: Neuro [Symbolic].

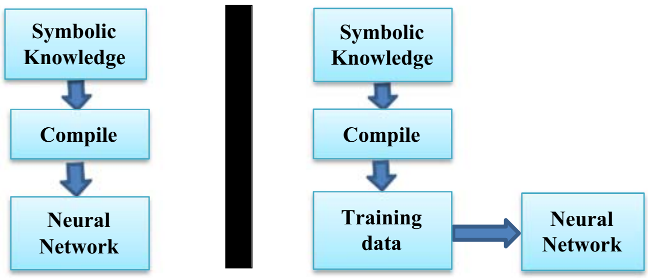

Figure 20.7 Type 6: Neuro: Symbolic $\longrightarrow$ Neuro.

Type 4: NeuroSymbolic

The structure of NeuroSymbolic is shown in Fig. 20.5. It turns symbolic knowledge into additional soft constraints in the loss function used to train DNNs thereby compiling knowledge into weights of neural networks.

Type 5: Neuro [Symbolic]

The structure Neuro [Symbolic] is shown in Fig. 20.6. The strength of logic-based and neural-based AI are combined as a fully integrated system. The symbolic reasoning system is built inside the neural network but their logic reasoning ability is relatively weak.

Type 6: Neuro: Symbolic $\longrightarrow$ Neuro

The structure of Neuro: Symbolic $\longrightarrow$ Neuro is shown in Fig. 20.7. The symbolic reasoning system gets the output of the neural network as input. Here symbolic rules/knowledge are compiled into the architecture of the neural network.

Logical neural network

The preparation of data is expensive, labor intensive and impractical hence thousands of Q and A sets are required to create an end—end education system hence a system is formed such that the natural language questions are converted into logical form. CNN uses a knowledge base for reasoning and generating answers.

The neural symbol inference technique incorporates rules on symbols that are linked with the knowledge base. The logical neural network supports both forward and backward propagation. Once the bounding box finds an object, the contextual properties of the object are extracted by the algorithm. Domain-specific language (DSL) translates natural language questions into computer-executable program.

Knowledge graph

It is the network that represents the real-world entities such as situations, and concepts and the relationship between them is illustrated and stored in a graph database. The structure of KG is shown in Fig. 20.8. Hamilton et al. (2022) state in their paper that KG uses natural language processing through nodes, labels and edges. KG is the modern implementation of AI. A comprehensive survey is performed on four scopes. They are as follows:

1. Knowledge representation learning

   It includes a representation space scoring function, encoding models and auxiliary information. Some of the encoding models are CNN, recurrent neural network (RNN), Transformer, GCN, and factorization. The scoring functions are distance

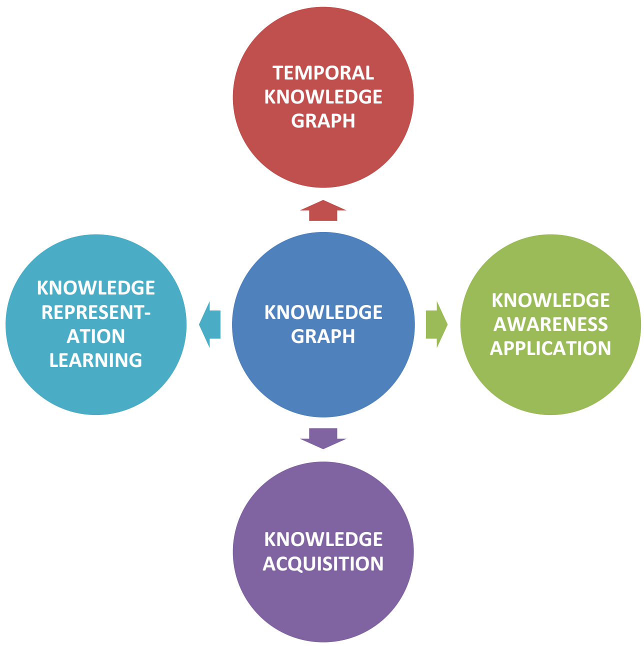

Figure 20.8 Knowledge graph.

and sematic matching. Representation space includes point-wise, complex and discrete functions.

2. Knowledge acquisition

   It includes entity discovery which is based on path-based, rule-based reasoning along with metarelational learning that involves recognition, typing and alignment. Relation extraction includes neural nets, GCN, GAN, RL, etc.

3. Temporal KG

   It is categorized into four research fields which include temporal embedding, entity dynamics, temporal relational dependency, and temporal logical reasoning.

4. Real-world knowledge awareness application

   It includes questions which are used in dialog and recommender systems and natural language understanding. The other applications include search engines, medical applications, text generation and sentiment analysis.

KGs are representations of vector space which are called knowledge graph embedding (KGE) which can increase the performance of machine learning models.

The three popular embedding algorithms are used. They are (1) TransE, (2) HolE, and (3) ConvK. KGE algorithms are classified into two primary categories: (1) transitional distance-based algorithms and (2) semantic matching-based models. The scoring function is defined by the former and the similarity measure is defined by the latter.

The second application is mainly concerned with the integration of knowledge which can be encoded in commonsense knowledge bases, the learning process is guided using question-answer tasks. A language model is applied to specialized modules which assess the questions and answers based on a common KG.

Both projects inherit a hybrid approach which is embedded with KGs. The explainability of the model is achieved using data-driven algorithm along with appropriate knowledge resources.

Knowledge-infused learning

DL improvised AI by increasing the capabilities of a machine to understand the data-dependent relationship. Knowledge is not directly related to the data but it just represents that the information acquired is true. The performance can be increased by fusing knowledge with data-driven DL techniques. The user-level explainability achieves better control over the AI system. This process of combining explicit knowledge with data-driven technique is called knowledge infusion. Guar et al. (2022) stated that many algorithms are used to infuse various knowledge into DL methods and they are shallow infusion, semi-dependent infusion and deep infusion.

The mapping of the tokens of input data to the concepts in the KG provides user explanation. The weighting function monitors the learning curve and demonstrates the relationship between the concepts in the knowledge source and tokens in the input. Shallow knowledge infusion captures meaningful patterns from data using expert knowledge. Semi-deep infusion embeds expert knowledge using constraints but it is unable to learn high-level abstraction through its multiple layers.

Knowledge infusion is the important force that drives the neuro-symbolic AI to the next generation. It will be applied to recommender systems, robotics, self-driving cars, computer vision and science engineering. Contextual adaptation and explanation are the two paradigms where explicit knowledge will play a significant role. There are various mechanisms in which knowledge can be injected into the model. They are key-value memory mechanisms proposed by Mihaylov and Frank (2018), Miller et al. (2016), and Bauer et al. (2018), for extrinsic scoring functions, graph convolution networks proposed by the authors Kipf and Welling (2016); Lin et al. (2019) and attention-based gating mechanisms proposed by Xue et al. (2018). The most acceptable knowledge type should be selected for a particular knowledge base with appropriate neural injection and pipeline for knowledge extraction. The experimental results finally prove that attention-based injection is best suited for knowledge fusion which eventually increases the performance of the model. There are two methods which is responsible for creating the sense-making ability of the model. They are knowledge-driven and data-driven methods. The understanding of the concept of embedding space using KG in automatic driving criteria proposed by the authors, Oltramari et al. (2020). The technical challenge in autonomous driving is scene understanding. In reality, it can be achieved by representing the entities in a scene and their relations are expressed using a KG.

KGs are representations of vector space which are called KGEs which can increase the performance of machine learning models. KGE algorithms are classified into two primary categories: (1) transitional distance-based algorithms and (2) semantic matching-based models. The scoring function is defined by the former and the similarity measure is defined by the latter. The second application is mainly concerned with the integration of knowledge which can be encoded in commonsense knowledge bases, the learning process is guided using question-answering tasks. A language model is applied to specialized modules which assess the questions and answers based on common KG. Both projects inherit a hybrid approach which is embedded with KGs. The explainability of the model is achieved using data-driven algorithm along with appropriate knowledge resources.

Neural-symbolic reasoning systems

In order to enhance the speed of reasoning capabilities, there are three methods proposed which are mentioned by Yu et al. (2023) which are shown in Fig. 20.9.

1. Reason for learning;
2. Learning for reasoning;
3. Reason−learning.

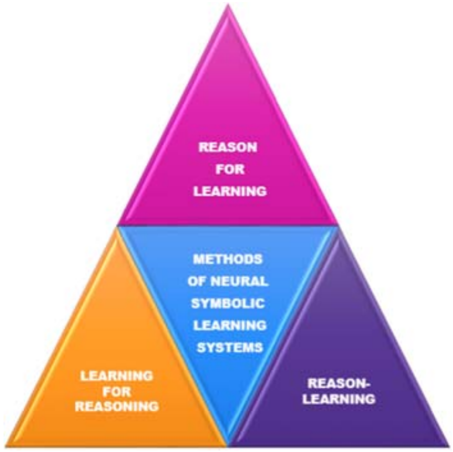

Figure 20.9 Methods of neuro-symbolic system.

Learning for reasoning

These methods aim to combine neural networks with symbolic reasoning to improve the efficiency and accuracy of reasoning processes.

The primary objective of both pLogicNet and ExpressGNN is to integrate the advantages of logic-based reasoning and neural networks into a unified framework. By doing so, they harness the scalability of neural networks and the expressiveness of logic rules to provide solutions for reasoning tasks within KGs.

pLogicNet: It aims to address the triplet completion problem in KGs by treating it as an inference problem with hidden variables in a probability graph. It constructs a joint probabilistic model that combines the logic rules encoded in the KG with a neural network model. This joint model captures the dependencies between observed and hidden variables, allowing for probabilistic reasoning. By combining the scalability of neural networks with the logic rules of KGs, pLogicNet enhances reasoning capabilities in KGs.

ExpressGNN: ExpressGNN builds on the foundation laid by pLogicNet. It improves the inference network of pLogicNet by introducing a graph neural network (GNN). Instead of using a flattened embedding table, ExpressGNN leverages GNNs to handle entity embeddings. Additionally, ExpressGNN addresses the issue of isomorphic nodes sharing the same embedding by introducing a tunable component in the entity embedding. This enhancement contributes to more effective reasoning within KGs.

Both models aim to unify neural networks and symbolic reasoning for improved reasoning within KGs. They bridge the gap between these two paradigms by using neural networks for scalability and logic rules for expressiveness, resulting in more powerful reasoning capabilities for complex tasks involving KGs.

Reasoning for learning

The interaction between neural networks and symbolic reasoning has led to the development of various reasoning-for-learning methods. These methods can be broadly categorized into two groups: regularization models and knowledge transfer models.

Regularization models

Regularization models are designed to integrate symbolic knowledge into the training process of neural networks. They achieve this by adding regularization terms to the objective function of the model. These regularization terms serve as constraints or penalties that encourage the neural network to adhere to the symbolic knowledge during training. The incorporation of prior knowledge in this manner aims to improve both the performance and interpretability of the trained model.

Regularization models use various strategies to model symbolic knowledge as regular terms, which may include:

Semantic Embeddings: These models can use embeddings to represent the relationships between symbols, enabling neural networks to learn from this structured knowledge.

Logical Rules: They incorporate symbolic logic rules into the training process, allowing the network to make decisions based on logical reasoning.

Semantic Constraints: They impose constraints on the neural network's activations, guiding them to align with the semantic information.

Knowledge transfer models

Knowledge transfer models facilitate the transfer of symbolic knowledge from one domain or space to another, such as from a semantic space to a visual space. These models leverage existing symbolic knowledge or semantic information to guide the learning of models in a different domain. The goal is to improve the performance and generalization of the model by utilizing symbolic knowledge from a different context. Knowledge transfer models can enable tasks like zero-shot learning or semantic segmentation by transferring semantic knowledge to aid in tasks that involve visual data.

Both regularization models and knowledge transfer models represent innovative approaches to enhancing the capabilities of neural networks by incorporating symbolic knowledge and leveraging it to guide the learning process. These approaches have the potential to enhance the performance, interpretability, and generalization of AI models in various domains.

Learning—reasoning

The concept of learning—reasoning represents an innovative approach to problem-solving that emphasizes the bidirectional interaction between neural systems (typically represented by neural networks) and symbolic systems. In learning—reasoning, both paradigms work in tandem, playing equal roles and mutually benefiting each other. The primary objective is to strike a balance between neural and symbolic systems, leveraging their respective strengths to enhance overall problem-solving capabilities.

Here's how learning—reasoning works:

Bidirectional interaction

Learning—reasoning emphasizes that the interaction between neural and symbolic systems should be bidirectional. This means that the output of the neural network feeds into the symbolic reasoning component, and the output of symbolic reasoning contributes to the neural network. This bidirectional flow of information allows both systems to influence each other.

Iterative exchange

The interaction between neural and symbolic systems is iterative. It's not a one-time process but rather a continuous exchange of information and influence. The systems take turns processing and making sense of data, with each iteration potentially refining the understanding of the problem.

Enhanced problem-solving

By embracing this bidirectional and iterative interaction, learning—reasoning approaches aim to maximize the strengths of both neural and symbolic paradigms. Neural networks are excellent at processing data and recognizing patterns, while symbolic reasoning excels at logic-based decision-making and knowledge representation. By combining these strengths, the approach seeks to achieve enhanced problem-solving capabilities across various domains.

Learning—reasoning is particularly valuable in domains where a deep integration of both neural and symbolic approaches is required to understand and address multifaceted challenges.

The iterative nature of learning—reasoning enables the systems to learn from each other and refine their collective understanding of the problem, ultimately leading to more informed and robust solutions. This approach represents a promising direction in the field of AI, as it seeks to harness the complementary strengths of neural and symbolic systems for more comprehensive problem-solving.

Noncommunicable diseases in Asia

In the Asia-Pacific region, numerous countries are poised to undergo a rapid demographic shift toward aging societies in the coming decades. Globally, the count of individuals aged 60 years and above is predicted to double by the year 2050.

This projected surge in the aging population coupled with a swift increase in the prevalence of lifestyle-related risk factors will contribute significantly to the rise of noncommunicable diseases (NCDs).

Yiengprugsawan et al. (2016) in their paper stated that NCDs account for a substantial portion of total deaths in the Asia region with a notable impact in areas like South-East Asia and the Western Pacific. Over the next few decades, there is an anticipated sharp escalation in the rates of NCDs in terms of both illness and mortality. While the origins of risk factors are spread across various life stages the manifestation and treatment of the majority of NCDs primarily affect older individuals.

NCDs tend to develop gradually across a person's lifespan progressively influencing functional abilities. Prominent NCDs encompass cardiovascular diseases (CVDs), diabetes various cancers, stroke and mental depression. There are also some rare diseases which are common in Saudi Arabia which require further analysis but due to the less number of datasets, we are unable to diagnose them properly.

This trend reflects a global concern as NCDs are a leading cause of death and disability worldwide. They are often linked to lifestyle factors such as unhealthy diets, lack of physical activity, tobacco use and excessive alcohol consumption. Addressing NCDs requires comprehensive efforts that span not only the healthcare sector but also broader social and economic domains. Prevention, early detection, access to quality healthcare and public health interventions are key components of tackling the NCD burden and improving the overall health of populations in the South-East Asia region and beyond.

NCD should be diagnosed earlier for the aging population using their habitual life history and the data are analyzed using DL. Using neuro-symbolic AI the knowledge is given to AI and the NCD diseases can be diagnosed at the earlier stage.

Narayan and Kanaya (2020) explain in their paper that the key points of the significant burden of diabetes, particularly type 2 diabetes, in the South Asian region. Nearly 2 billion people are affected by type 2 Diabetes in South Asia. This phenomenon is often referred to as "South Asian Phenotype" or "South Asian Diabetes." It's important to note that South Asians are a diverse group with variations in genetics, culture, and lifestyle. Not everyone from this population will develop diabetes, and there are efforts to promote healthier lifestyles and improve diabetes awareness and care in South Asian communities. These statistics underscore the urgent need for diabetes prevention, early diagnosis, and effective management in the South Asia region to mitigate the significant health and economic impact of this disease.

Wada et al. (2023) describe in their paper that stroke is a significant health concern in Asia, with a high prevalence and impact on public health. He emphasizes the importance of healthcare system infrastructure and standardized care protocols in improving survival rates for stroke patients. These findings can inform strategies for stroke care and management in different countries to reduce stroke-related mortality.

Asia has a high prevalence of stroke, with countries in East and Southeast Asia often experiencing higher rates. This prevalence is influenced by various factors, including genetics, lifestyle, and an aging population.

Zhao (2021) state in their paper that Asian countries are in the second stage of the rapidly increasing CVD epidemic. In these countries such as Georgia, Azerbaijan, Uzbekistan, Turkmenistan, China, and Mongolia, the CVD mortality rates are quite high, CVS is a significant public health issue in the Asia-Pacific region. It is the leading cause of death in the Asia-Pacific region, accounting for 35% of all deaths in 2019. Ischemic heart diseases were a leading cause of death, contributing to 25.4% of total deaths in South-East Asia. These findings highlight the urgent need for effective strategies to prevent and manage CVDs in the Asia-Pacific region.

Rajappa et al. (2023) state that there is an increasing incidence of new cancer cases in Asia, as estimated from 6.1 million in 2008 to 10.6 million in 2030. One of the primary drivers of the rising cancer incidence is the aging population. Cancer survival is one of the key measures of the effectiveness of healthcare systems in managing cancer, reflecting both early detection and the effectiveness of treatment. As more people move from rural areas to urban centers, they may adopt less healthy lifestyles, such as sedentary jobs and access to less healthy foods.

Padma Usha et al. (2023) described the novel technique, utilizing Berkeley's wavelet convolutional transfer learning and Gabor fuzzy C-means clustering for brain tumor tissue diagnosis, in the field of medical imaging and analysis. The Berkeley wavelet convolutional transfer learning suggests a method of pretrained neural networks or models (such as CNNs) that are adapted to the task of identifying brain tumors. This technique leverages wavelet transformations in the feature extraction process. Wavelets are mathematical functions useful in transforming data into frequency space, often used for feature extraction in signal processing. The Gabor fuzzy C-means clustering is an image segmentation technique. It's a fusion of Gabor filtering (a method used in image processing for edge detection) and fuzzy C-means clustering, which is a machine-learning algorithm for grouping data points into clusters. The reported accuracy of 98.7% suggests that this combined approach is highly effective in diagnosing brain tumor tissues from medical imaging data.

Rare disease prediction

A comprehensive overview of the challenges and opportunities related to the application of DL in rare disease research. The prevalence of rare diseases collectively affecting a significant portion of the population underscores the importance of finding innovative solutions for diagnosis, care and research. The wide-ranging impact of these diseases on patients and their families necessitates effective tools and techniques to improve both diagnosis and treatment.

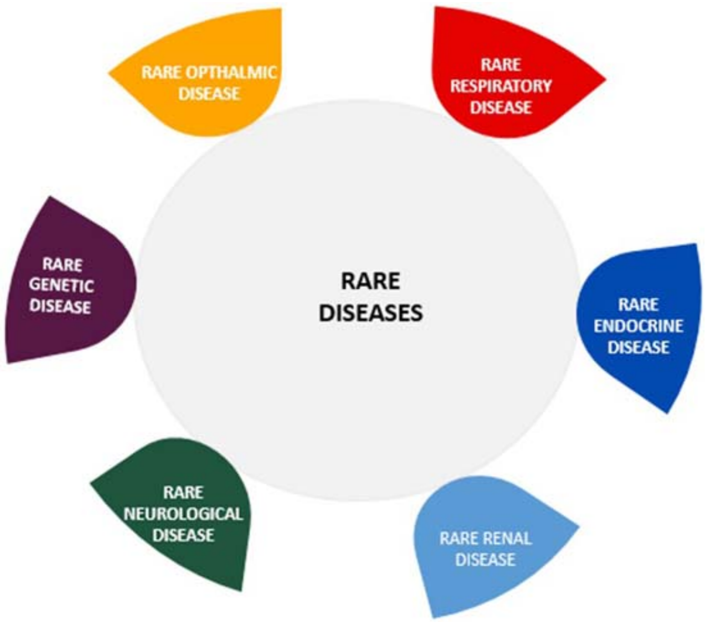

Figure 20.10 Different rare diseases.

DL's potential in healthcare including rare disease research is evident from the review of articles. The rare diseases are classified from Genetic diseases to ophthalmic disorders which is shown in Fig. 20.10.

The identification of diagnosis as a primary focus highlights how DL can play a crucial role in enhancing early detection and accurate diagnoses of rare diseases. While DL offers significant promise, the challenges associated with data availability, model interpretation, and generalization still need to be addressed to fully harness its potential in this domain.

A research paper addresses several key aspects related to rare conditions in Saudi Arabia. Alsaqa and Ibrahim (2019) discuss the prevalence of rare conditions in the country, shedding light on the unique healthcare challenges posed by these conditions due to their rarity and complexity. Secondly, the paper examines the current reimbursement methods and policies for rare conditions in other countries. This comparative analysis allows the researchers to understand the various approaches used worldwide and identify potential best practices that could be adopted or adapted to the Saudi Arabian context.

Thirdly, the paper explores the limitations and challenges associated with the use of typical methods of economic evaluation in the context of rare conditions. Economic evaluations play a crucial role in determining the cost-effectiveness and value of medical interventions, but they may not fully capture the specific nuances and complexities of rare conditions.

Overall, this paper provides valuable insights into the unique healthcare challenges posed by rare conditions in Saudi Arabia and offers potential solutions to improve the funding and reimbursement mechanisms for patients with these conditions.

There is a lack of data on the prevalence and incidence rates of rare diseases in the country, making it difficult to assess the true burden of these conditions. There is a dearth of economic and humanistic burden data associated with rare diseases, as well as a lack of national registries that could provide valuable information to healthcare providers and researchers.

There are significant challenges that DL faces when applied to rare diseases. These challenges indeed play a crucial role in determining the effectiveness and applicability of DL techniques in this domain. Insufficient data, poor data quality and issues related to model evaluation and validation are common obstacles that can hinder the development and deployment of reliable deep learning solutions. Additionally, the complexity of training DL models, the interpretability of their decisions and the ability to generalize findings to diverse populations are important aspects to consider when addressing rare diseases with AI. Overcoming these challenges requires interdisciplinary collaboration and continuous advancements in both the DL algorithms and the understanding of rare diseases themselves.

Neuro-symbolic AI can overcome these issues by incorporating knowledge related to these diseases into the model and thereby predicting the disease at an early stage which can guide the aged people at the early stage of the disease.

Application of neural-symbolic artificial intelligence

Alzheimer’s disease prediction

Alzheimer’s disease is a global concern and its impact is felt across diverse populations, including those of Asian descent. As life expectancies increase and populations age, Alzheimer's disease and other forms of dementia pose significant challenges to healthcare systems and families worldwide. It’s important to address these concerns in culturally sensitive and region-specific ways.

Different Asian countries and communities have unique cultural beliefs, values, and attitudes toward aging and healthcare. Different factors can influence Alzheimer’s disease in the Asian region which is shown in Fig. 20.11.

This disease is a common one to all the aged people in and around Asia. In this research paper, the author, Lavin (2022) introduces about a novel methodology termed **“probabilistic programmed deep kernel learning”** for the purpose of personalized and predictive modeling of neurodegenerative diseases.

The study delves into a range of neural and symbolic machine learning techniques, meticulously evaluating their predictive performance along with their significance in

Figure 20.11 Factors causing Alzheimer's in Asians.

the realm of medical AI. Key attributes, including interpretability, uncertainty reasoning, data-efficiency and the leveraging of domain knowledge are scrutinized.

This innovative approach synergistically merges the adaptability inherent in Gaussian processes with the robust capabilities of neural networks. Its principal objective is to effectively model the progressions of biomarkers that are pertinent to various neurodegenerative diseases. Rigorous evaluations have been conducted, particularly in the context of predicting Alzheimer's disease, showcasing remarkable performance advantages over conventional deep learning methodologies. Notably, the proposed approach outshines its counterparts in terms of accuracy and speed in forecasting neuro degeneration.

One of the distinct strengths of this approach lies in its practical advantages, notably its incorporation of Bayesian nonparametrics and probabilistic programming. These features significantly contribute to the resilience and dependability of the presented models. Furthermore, the inclusion of domain knowledge pertaining to the targeted disease augments the system's performance, particularly in the early stages of disease progression.

Automatic regeneration for spinal medical report generation

Automated medical report generation in the realm of spine radiology represents a complex yet pivotal challenge within the field of AI in healthcare. Han et al. (2021)

are dedicated to the creation of diagnostic reports with the proficiency of radiologists, utilizing spinal medical images to facilitate clinical decision-making.

The foundation of this undertaking is the groundbreaking neural-symbolic learning (NSL) framework, which masterfully amalgamates the capabilities of deep neural learning and symbolic logical reasoning, emulating a cognitive learning approach akin to human thinking. The NSL framework embarks on its journey by harnessing the power of deep neural learning to replicate human visual perception.

This initial phase proves instrumental in detecting anomalies present in specific spinal structures. To achieve this, **a novel adversarial graph network** is introduced. This network ingeniously integrates a symbolic graph reasoning module into a GAN. Through the incorporation of domain-specific knowledge, this network excels in semantically segmenting the intricate and inherently variable spinal structures.

The NSL framework, at its core, represents a harmonious synergy between the capabilities of neural networks and symbolic reasoning. By seamlessly weaving together these diverse strengths, the framework aims to advance the comprehension and diagnosis of spinal conditions by effectively identifying anomalies through data-driven insights while also providing logical reasoning and interpretability through symbolic manipulation. This approach holds great promise in the realm of medical imaging and diagnostic decision-making. There is a lack of common connection between the two concepts and Zhong et al. (2018) introduced a method called ConceptNet which improves the question-answering concept.

Upon identifying abnormalities, the NSL framework embarks on symbolic logical reasoning, mirroring human-like thought processes through metainterpretive learning. This phase facilitates an unsupervised analysis of causal relationships among the detected entities, thus enhancing the understanding of interconnections between abnormalities and other contributing factors.

Ultimately, the NSL framework amalgamates these insights into a unified template, leading to the generation of comprehensive medical reports. Rigorous empirical evaluations using real-world clinical datasets validate the efficacy of this approach, particularly in the realm of detecting spinal structures. This underscores the potential of NSL as a valuable clinical tool for computer-aided diagnosis.

Neuro-symbolic artificial intelligence in mental healthcare

The aged people are greatly affected due to mental health as there is no one to take care and give affection to them. In the domain of Mental Health Care (MHCare), there is a need to enhance neural-AI systems by integrating clinical symbolic knowledge that clinicians use in their decision-making processes is stated by the author Roy et al. (2022). One powerful application of neural-AI in MHCare is **conversational systems**, which can facilitate humanistic conversations with conversational agents

(CAs). However, existing CAs with deep language models often lack factual accuracy, medical relevance, and safety in their generated responses, which can be problematic, especially in mental health contexts.

This paper aims to showcase the potential of neuro-symbolic approaches in improving neural-AI systems for MHCare interventions. By integrating clinical knowledge, these systems can provide more accurate, relevant, and safe responses to mental health-related queries, ultimately leading to better support and care for patients in the mental health domain.

Explainable artificial intelligence

Diaz-Rodriguez et al. (2022) state that explainability of DL algorithms plays an important role in explaining why things go wrong and why things work well. There are different measures to capture the interpretability and XAI has become a hot topic in DL. Some of the XAI libraries included are Pytorch, Tensorflow, etc. There is an interpretability assessment criteria that helps the DL community to keep track of the algorithm which can be improved further. The terms reliability and trustworthiness are the other words of explainability.

The true models should generate reasoning with explanation by signifying the high-level features with a reasoning error that should find a mistake in a black box. Toja and GuAN (2021) developed a model, that should be capable of giving an explanation on what the system should conclude when looking at those features and also the reason behind it. There are various methods used for explainability in a model and some of them are LIME, GraphLIME, Anchor, LRP, DTD, PDA, TCAV, and explainable neuro-symbolic learning.

Example of an explainable neural-symbolic model

Anaya-Isaza et al. (2021) explained the concept of the "black box" representation by the output provided by a caption, wherein the explanation is subsequently furnished by a reasoner. In this scenario, external user or expert knowledge remains detached from the prediction process, ensuring that the model operates as a truly explainable entity, effectively conveying the rationale behind its output decisions. Notably, this process adheres to a faithful and transparent communication of the underlying reasoning. An example of neuro-symbolic explainable model is shown in Fig. 20.12.

Throughout the training phase, the model undergoes a progression that ensures interpretability is maintained at each juncture. This approach fosters a comprehensive understanding of the model's decision-making process.

The model in question, which is devoid of a knowledge base, is constructed through learning from neural network data. This enables the model's learning process to be influenced and any biases to be rectified, ultimately culminating in detailed

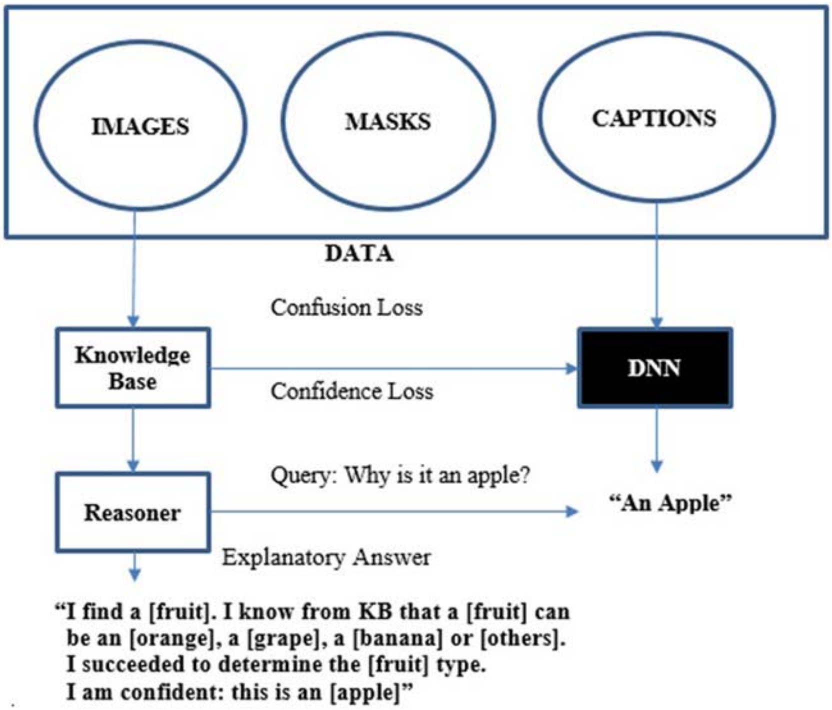

Figure 20.12 An example neuro-symbolic explainable model.

explanations for its predictions. This methodology finds application across various domains, encompassing scientific discovery, programming systems, question answering, robotics and control, visual scene understanding, and even mathematical reasoning. By adopting this approach, a model becomes an instrumental tool for generating fine-grained explanations, thereby enhancing its utility and transparency in multiple arenas.

Current trends in different applications using explainable artificial intelligence

Diabetic retinopathy (Dr) is the most common disease that affects the elderly in Asia. Quellec et al. (2021) explained the work of Dr classification using color fundus photography (CFP). In this research paper, novel approach called ExplainDR for Dr classification is proposed, which aims to achieve both explainability and interpretability in the classification model.

In order to achieve explainability, the author incorporated a high-level symbolic representation in the decision-making process. This representation follows a taxonomy-style structure of diabetic retinopathy characteristics related to eye health conditions, making it human-readable and interpretable.

By incorporating a human-readable symbolic representation and leveraging it for feature extraction, the model achieves competitive performance while providing valuable insights and transparency in the classification process. This contribution can have significant implications in the medical field, aiding clinicians in making informed decisions and improving patient care for diabetic retinopathy.

Sheth et al. (2022) discussed the case of utilizing AI for diagnosing the severity of depression. In this scenario, the AI system must seamlessly incorporate process knowledge that aligns with established clinical decision-making protocols. An example of such process knowledge could be the utilization of the Patient Health Questionnaire (PHQ-9), which serves as an essential tool in the clinical evaluation of depression.

Arrietaa et al. (2020) delve into enhancing the interpretability and explainability of classical CNNs. In pursuit of this goal, the author introduces a novel methodology, specifically, a distinctive loss function is used for each filter in the high-level convolutional layers. This unique approach is designed to compel each filter to specialize in learning specific components related to objects within the data.

As a result of this process, the activation patterns obtained from these specialized filters become inherently more interpretable. The discernible activation patterns serve as visual cues that aid in understanding the features being detected by the filters. This development significantly increases the transparency and intelligibility of CNN's operations.

Moreover, the author supplements this approach by incorporating posthoc techniques from the realm of XAI. These techniques are specifically chosen to further enhance the interpretability of the model by providing insightful explanations for the decisions it makes. By combining the specialized loss functions with posthoc XAI techniques, the author successfully elevates the overall interpretability and explainability of classical CNNs.

This advancement in the field of model interpretability holds tremendous potential, particularly in applications where understanding the inner workings of CNNs is crucial for decision-making, validation, and broader acceptance of AI-driven outcomes.

Adadi and Berrada (2018) gave a clear view of the model in terms of justify, grow, improve, and discover. These tools are helpful in getting various information to get new facts which directly promote gaining knowledge. The best example is Alpha Go Zero which can perform better than human beings such that the model can explain the learned strategy which is the knowledge to the human beings. The model can predict even hidden things in various subjects such as physics, biology, chemistry, etc. with explainability.

Mamalakis et al. (2022) attained explainability for the model which is developed for earth science in the prediction of weather, subseasonal climatic change, etc. The results from the satellite application are provided and converted into a dataset for the appropriate selection of models with explainable features.

Selvaraju et al. (2017) proposed a gradient-weighted class activation mapping (Grad-CAM) which uses the gradients of any target concept, flowing into the final convolutional layer to produce a coarse localization map which highlights the important regions in the image in order to predict the concept.

Lamya et al. (2019) proposed a CBR method which is an analogical reasoning that can be automatically executed as an algorithm and presented for visual reasoning and interpretation. The queries are classified in an explainable manner and it is combined using quantitative and qualitative approaches. This methodology is applied to breast cancer cases which were tested on three public datasets in which a qualitative method has better accuracy which has better explainability.

Saraswat et al. (2022) proposed an architecture which introduces an ensemble of EXAI techniques within the context of CT image classification and segmentation processes. It also introduces a taxonomy that categorizes the application of EXAI within the scope of Healthcare 5.0, emphasizing its relevance and potential impact. Throughout the discussion, the article highlights operational challenges that need to be addressed when implementing EXAI in healthcare contexts.

Furthermore, a detailed case study is provided, focusing on the monitoring of electrocardiogram data. In this case study, the article demonstrates the use of federated learning and EXAI to ensure the privacy of local models while validating the performance metrics. This case study serves to showcase the practical applicability of the proposed EXAI approach in a specific healthcare scenario.

Newman-Norlund et al. (2020) proposed the repository of both raw and processed neuroimaging datasets encompassing functional, resting-state, and structural MRI data are analyzed in addition to resting-state EEG data. This array of neuroimaging information offers insights into the brain's intricate dynamics. Complementing this, the repository also includes physiological measurements such as pulse and blood pressure, as well as vital blood data including CBC with differential, CMP, hA1c, B12, and Folate levels. Genetic data in the form of FMR1 data from buccal swabs is also available.

Furthermore, the repository encompasses calculated scores derived from a variety of well-established cognitive tests, along with less common measures that evaluate language use and processing capabilities. This breadth allows for a holistic understanding of cognitive faculties. Additionally, health-related self-report measures and demographic information provide context to the collected data.

The distinctiveness of this dataset lies in its capacity to enable researchers to explore the intricate interplay between healthy aging and a diverse range of factors, including brain dynamics, genetics, and behavioral attributes. The repository's comprehensive nature empowers researchers to undertake inquiries that are unparalleled by any other existing database, thereby fostering groundbreaking insights into the complex realm of healthy aging.

Neuro-symbolic artificial intelligence for early diagnosis of diseases

Healthier aging will result only from proper early diagnosis of diseases. The general workflow of neuro-symbolic AI for the prediction of any age-related disease is shown in Fig. 20.13. The knowledge about the particular disease will be given as facts to the model which increases the performance of the model thereby increasing the performance and explainability of the model using knowledge infusion techniques.

The process of integrating neuro-symbolic AI involves several key steps, each contributing to the synergy of neural networks and symbolic reasoning. Here's a breakdown of the process:

The process begins with preparing the data known as **data preprocessing**. This involves cleaning, extracting relevant features, and normalizing the data. In this case, the data consists of images for predicting diseases early in order to promote healthier living among the elderly.

Neural networks, particularly **DL models**, are employed to learn intricate patterns and representations from the raw data. Different architectures like CNNs for images, RNNs for sequences or Transformers for various data types can be used. This phase focuses on tasks like pattern recognition, feature learning, and data-driven representations. CNN is used widely for early detection of disease. The next step involves the integration of neural network outputs with symbolic reasoning.

The core innovation in neuro-symbolic AI lies in **merging** neural network outcomes with symbolic reasoning. This involves transforming the activations or learned representations of the neural network into a format suitable for symbolic manipulation. Techniques such as feature extraction, entity recognition, or embedding into a symbolic logic framework can be employed.

Symbolic reasoning in which the neural network outputs are converted into a symbolic format and traditional symbolic reasoning methods come into play. This includes tasks like logical inference, knowledge representation, and rule-based systems. Symbolic reasoning allows explicit handling of relationships such as logic rules, and

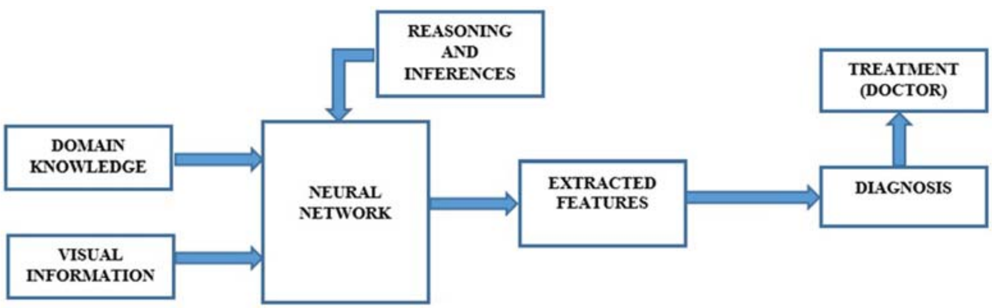

Figure 20.13 Workflow of neuro-symbolic artificial intelligence.

structured information. The hybrid inference is followed in which the primary advantage of neuro-symbolic AI is the capacity for hybrid inference where probabilities derived from neural networks and symbolic logic-based reasoning are combined. This could involve refining neural network predictions using logical constraints or utilizing symbolic reasoning to guide neural network decisions.

Interpretability and **Explainability** are significant benefits of neuro-symbolic AI which improves interpretability and explainability. Symbolic reasoning allows for transparent decision-making, contrasting with black-box neural network models.

The exact workflow can vary based on the chosen neuro-symbolic AI architecture, the domain of application, and the specific problem under consideration. The integration of neural networks and symbolic reasoning offers a potent approach to solving intricate problems that necessitate both data-driven insights and logical deductions.

Conclusion

Digital healthcare in the Asia and Gulf region emphasizes the urgent need to bridge the digital divide and invest in broadband infrastructure to ensure equitable access to technology. The evolving landscape of neuro-symbolic AI and its extensive applications within the healthcare sector is explored, with a meticulous analysis of the advancements and achievements in CNNs and their successful resolution of prior limitations associated with DL.

Furthermore, we delve into the seamless integration of neuro-symbolic AI in diagnosing age-related diseases, elucidating how this fusion significantly elevates diagnostic accuracy and makes a substantial impact on patient care in Asia. While many Asian countries actively integrate AI solutions into healthcare, some face challenges due to factors such as infrastructure and regulations. Notably, countries like Nepal, Myanmar, Cambodia, Bhutan, Mongolia, and Laos are in the early stages of AI adoption, with limited access to advanced AI technologies in rural areas.

In contrast, Gulf countries are generally known for their high-quality healthcare systems, featuring advanced medical facilities and well-trained professionals. However, they encounter various challenges, with the burden of NCDs, including diabetes and CVDs, on the rise, straining healthcare resources.

In light of these observations, we identify several policy implications for AI in healthcare within the Asian context. Firstly, governments in Asia need to establish clear regulations and standards for the development and use of AI in healthcare. Secondly, policymakers should invest in public awareness campaigns to educate citizens about the benefits and limitations of AI in healthcare, fostering trust and acceptance of these technologies. Thirdly, AI can enhance telemedicine services, and governments should develop policies that support the expansion of telemedicine while ensuring the quality of care provided.

Moreover, policymakers should ensure that AI systems adhere to strict data privacy and security standards to safeguard patient information. Addressing issues such as informed consent, transparency, accountability, and responsible AI use in healthcare decision-making is essential. We also introduce a comprehensive neuro-symbolic framework for early disease prediction in the elderly, with potential applicability across all Asian countries, especially in areas with limited data resources. This framework not only underscores the necessity for transparent and interpretable models but also highlights the practical applications of explainability in healthcare diagnostics.

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CHAPTER 21

The evolution and challenges of healthcare policy and research in the Middle East

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Introduction

The healthcare research sector in the Middle East is experiencing a significant transformation period, progressing from an early growth stage to a substantial contributor to the worldwide body of medical knowledge. The Middle Eastern nations have traditionally relied on insights and discoveries from the Western world. However, they are now not only adapting these insights to their unique context but also leading the way in conducting research suited to the unique demands of their diverse populations (Al-Wathinani, 2023).

Nations such as the United Arab Emirates (UAE), Qatar, and Saudi Arabia are leading the way in the current upsurge of healthcare research. These nations have acknowledged the significant significance of research in the progress of medical science and have integrated healthcare priorities into their national vision statements. Consequently, they have allocated considerable resources toward this endeavor (Brahimi & Sarirete, 2023). The Dubai Health Strategy 2021 places significant emphasis on promoting innovation and research as key drivers in establishing a healthcare system of global excellence (DHA, 2021). Similarly, Qatar's National Health Strategy emphasizes the importance of research in defining the trajectory of its healthcare landscape (Ministry of Public Health, 2017).

Several institutions in the region provide state-of-the-art facilities and cultivate an environment conducive to scholarly discourse, frequently organizing international conferences and facilitating partnerships with esteemed research organizations worldwide.

Nevertheless, the expedition is not devoid of intricacies. The region known as the Middle East encompasses a diverse array of nationalities, cultures, and traditions. The characteristics above present a distinctive benefit in studies involving a diverse patient population, particularly in genetics and epidemiology. However, it also presents specific difficulties when it comes to the development of research procedures. The study of many subjects, particularly in sensitive domains such as women's health or genetic

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research, necessitates a comprehensive comprehension of local customs, beliefs, and ethical considerations due to the socio-cultural fabric of the location.

A complex combination of factors characterizes the health concerns present in the region. The increasing incidence of noncommunicable diseases, including diabetes, obesity, and cardiovascular diseases, can be attributed to the process of urbanization and the resulting changes in lifestyle. Concurrently, the region is confronted with infectious diseases that are further intensified by regional wars, resulting in the relocation of populations and placing a significant burden on healthcare systems in specific regions. The presence of this twofold difficulty requires the implementation of a research strategy that encompasses many approaches in order to guarantee the provision of comprehensive healthcare solutions for the region's population (Tariq, 2022).

The Middle East, a region renowned for its extensive historical background and heterogeneous societies, has witnessed notable advancements in healthcare research during recent years. The convergence of escalating economic prosperity, heightened investment in education, and an amplified focus on research and development has resulted in significant progress within this particular domain.

One positive aspect of these issues is the observable increase in research productivity. An increasing trend is observed wherein more researchers from the Middle East are being prominently included in renowned worldwide journals, thereby highlighting the high caliber and pertinence of their research contributions. Incorporating cutting-edge technology, including artificial intelligence (AI), telemedicine, and big data analytics, into the healthcare research framework is augmenting the region's prominence worldwide (Shaikh, 2023).

One of the most notable transformations in the healthcare sector of the Middle East involves the heightened allocation of resources toward infrastructure development. Nations such as the UAE, Saudi Arabia, and Qatar have allocated significant money to establish cutting-edge research centers and hospitals. These nations have acknowledged the significance of healthcare research, not only for the welfare of their populations, but also as a strategy to broaden their economies beyond conventional sectors like oil and gas (Bandyopadhyay, 2023).

There is an increasing focus on fostering joint research endeavors, both at the regional level and in conjunction with foreign counterparts. Universities in the Middle East are actively establishing collaborative alliances with internationally acclaimed institutions, facilitating the interchange of knowledge and developing a culture of innovation. The collaborative efforts have resulted in significant advancements across various disciplines, encompassing genetics and infectious illnesses.

Due to the distinctive health-related obstacles encountered in the Middle East, a significant portion of the research focuses on this region's prevailing conditions. The conditions above encompass genetic problems, diabetes, cardiovascular ailments, and specific forms of cancer. Furthermore, a collective endeavor exists to investigate and tackle health concerns that emerge as a result of alterations in lifestyle patterns, the process of urbanization, and various environmental influences.

The present discourse revolves around the challenges that are being faced and the potential pathways for progress.

Notwithstanding the advancements made, there are enduring issues that remain. There is a demand for more individuals who possess specialized training, enhanced regulatory frameworks, and sustainable financial models. Furthermore, it is imperative to acknowledge the significant discrepancy in healthcare research and infrastructure between the prosperous Gulf states and the less economically advantaged countries in the same region.

The following section talks about the background, third section is about the historical perspective, fourth section is about the current landscape, fifth section is about the challenges, sixth section is about implications for policy, and the last section ends the chapter with the conclusion and future agenda.

Background

The Middle East is experiencing substantial changes in multiple sectors, including healthcare, due to its rich cultural heritage, historical background, and different socio-economic structures. Healthcare research has become crucial in the current complex and ever-changing environment. Its role is to support decision-making based on evidence and to influence public health policies and agendas that align with the specific requirements and goals of the region. There are several compelling justifications for the indispensability of healthcare research within the Middle Eastern milieu (Ismail, 2021). Cultural sensitivity is a crucial aspect of healthcare, since it recognizes the inadequacy of a one-size-fits-all approach to healthcare practices. The diverse array of cultures, traditions, and beliefs throughout the Middle East has significant implications for health-seeking behaviors, treatment adherence, and perception of sickness. Through the implementation of localized research, policymakers have the opportunity to design culturally responsive health programs, thereby enhancing their efficacy and fostering more acceptance among the populations they aim to serve (Azizi, 2019).

Health system strengthening is a critical area of focus within healthcare research, as it provides valuable insights into the healthcare system's overall efficiency, equity, and efficacy. Research is crucial in facilitating informed reforms and investments in healthcare infrastructure by evaluating service availability and quality, identifying bottlenecks, and assessing health finance methods (Hanney, 2020). Addressing Emerging Threats: The Middle East region has been confronted with several emerging health threats, encompassing health system disruptions resulting from conflicts and the emergence of novel infectious diseases. Healthcare research facilitates the implementation of real-time surveillance, timely identification, and prompt response, hence minimizing the detrimental consequences of such risks. Technology integration into healthcare delivery holds significant potential for the Middle East, given the global upsurge in healthcare tech solutions. Research plays a crucial role in fostering innovation by evaluating the practicality, desirability, and effectiveness of novel technologies and treatments, hence assuring their alignment with the unique requirements of the given region (Docea, 2020).

The formation of evidence-based policies is crucial for ensuring their effectiveness. The research findings provide concrete evidence that assists policymakers in formulating precise recommendations, making prudent resource allocations, and monitoring and assessing the effects of health programs.

The involvement of various stakeholders is a common practice in healthcare research conducted in the Middle East, wherein partnership is established among governmental bodies, academic institutions, international organizations, and civil society. Collaboration of this nature promotes a comprehensive approach to health concerns, so guaranteeing the inclusion of varied perspectives and resulting in the formulation of more complete and inclusive policies.

Historical perspective

The examination of healthcare research in the Middle East provides an intriguing insight into the wider transition occurring in the region, which parallels its socio-economic, political, and technical changes. The following is a concise summary of the evolutionary progression of the subject matter.

The Middle East is commonly recognized as the birthplace of civilization, encompassing significant contributions to the domains of medicine and health. During the early 11th century, Avicenna (Ibn Sina), a prominent historical figure hailing from Persia, authored the renowned medical text known as the "Canon of Medicine" (Ghaffari, 2022).

The period from the 1970s to the 1990s witnessed an oil boom and subsequent modernization. The exploration and subsequent exportation of oil in numerous Middle Eastern nations precipitated swift socio-economic advancement and affluence. During this time frame, there were notable allocations of resources toward the development of hospital facilities, educational systems, and provision of services. The establishment of universities and research institutions marked the initiation of a more organized and systematic approach to health research (Wilson, 2021).

In the 21st century, the Middle East has experienced a notable increase in specialized medical research, coinciding with the era of globalization. Various factors have propelled focused study, including the upward trajectory of life expectancy, evolving lifestyle patterns, and the complex landscape of communicable and noncommunicable diseases. Nations such as Saudi Arabia, Qatar, and the UAE have made substantial investments in establishing and developing medical universities, research institutions, and international partnerships (Al Salman, 2021). The Middle East has demonstrated a keen embrace of health technology in recent decades, leading to significant technological integration throughout the region. Research and implementation have been observed in various domains, such as digital health records, telemedicine, AI in diagnostics, and genomic projects (Al-Samarraie, 2020). The prevalence of cross-border collaborations within the Middle East and partnerships with foreign entities has increased in contemporary times. Collaborative research endeavors between esteemed institutions such as the World Health Organization (WHO) and worldwide universities are common, facilitating the reciprocal transfer of knowledge and specialized skills. There is a growing trend toward prioritizing patient-centered outcomes, quality of treatment, and community engagement within the realm of health research. This transition guarantees that the study conducted is more pertinent and advantageous to the groups it caters to.

The evolution of healthcare research in the Middle East can reflect its transition from ancient knowledge to contemporary advancements, characterized by continuous adaptation and innovation in response to internal dynamics and global changes. The continuous process of evolution in the region ensures that it is more effectively prepared to tackle its distinct health concerns and make valuable contributions to the global body of medical knowledge.

Current landscape

Several Middle Eastern nations, particularly the UAE, Saudi Arabia, and Qatar have made substantial investments in the development of advanced medical facilities and research establishments. These institutions address the needs of the local community and draw intellectuals and researchers from around the world. Current research endeavors are progressively focused on comprehending and mitigating these regional epidemiological patterns. Genomic research endeavors have been undertaken by nations such as Saudi Arabia and Qatar to comprehensively map their indigenous peoples' genetic makeup. The primary objective of these undertakings is to comprehend the genetic underpinnings of ailments that are widespread in the specific geographic area, hence facilitating the advancement of personalized medication (Mbarek, 2022).

The Middle East region has demonstrated a strong inclination toward the implementation of digital health solutions, encompassing a range of technologies such as electronic health records and telemedicine. In addition, nations such as the UAE are currently investigating the incorporation of AI in the fields of diagnostics, predictive analysis, and personalized treatment strategies (Qoronfleh, 2020).

Leading institutions and centers of excellence

While pursuing modernization and achieving high standards, the Middle East has witnessed the establishment of healthcare facilities that are globally recognized for their excellence. These centers offer exceptional medical care and excel in research, innovation, and training. An overview of prominent institutions and centers of excellence within the region is presented here.

The King Faisal Specialist Hospital & Research Center (KFSH&RC) is a prominent healthcare institution located in Saudi Arabia. KFSH&RC, founded in the 1970s, is a prominent tertiary care establishment in the Middle East. Renowned for its specialized medical divisions, cutting-edge research, and advanced training programs, the institution has branches in Riyadh and Jeddah (Mousa, 2021). Cleveland Clinic Abu Dhabi, located in the UAE, is a collaborative effort between the UAE government and the Cleveland Clinic in the United States. This medical facility provides advanced patient care, leveraging the expertise and reputation of its American counterpart while also addressing the specific healthcare requirements of the Middle Eastern population (Fitzmaurice, 2020). Hamad Medical Corporation in Qatar serves as the leading nonprofit healthcare provider in the country, overseeing the management of several hospitals and providing sophisticated medical services in various specialized fields. With a focus on future developments, the organization consistently enhances its services, infrastructure, and research capacities (Mohamed, 2021). These institutions exemplify the Middle East's dedication to achieving high standards in healthcare, highlighting the amalgamation of global partnerships with indigenous proficiency. They assume a crucial role in enhancing the region's healthcare standards, research capacities, and medical education.

Challenges

The Middle East has historically served as a significant nexus of geopolitical tensions and conflicts. The region has been characterized by political instability for several decades, encompassing interstate conflicts, civil unrest, and insurgencies. The consequences of this instability are many, and its effect on healthcare is significant and diverse, frequently intensifying existing difficulties and giving rise to novel ones. In areas of active warfare, there is a frequent occurrence of intentional or unintentional attacks on medical facilities, resulting in significant damage to infrastructure. During times of armed conflict, healthcare facilities such as hospitals, clinics, and pharmacies sometimes suffer significant damage, resulting in the deprivation of crucial healthcare services within affected populations (Ahern-Flynn, 2023). The relocation of populations is a consequence of armed conflicts and political upheavals, resulting in significant demographic shifts. Refugees and internally displaced individuals often find themselves residing in camps or improvised settlements where their access to healthcare, clean water, and sanitation is severely restricted. Consequently, they become susceptible to various diseases and epidemics, hence exacerbating their vulnerability. The scarcity of medical professionals can be attributed to political instability, which frequently leads to the migration of highly trained individuals, such as doctors, nurses, and other healthcare practitioners. The phenomenon of brain drain exacerbates the difficulties associated with delivering sufficient healthcare services to the population in question. Political instability frequently diverts resources and attention away from the implementation of preventive healthcare measures. The prioritization of vaccination campaigns, health check-ups, and awareness programs is diminished, resulting in avoidable outbreaks and enduring health ramifications (Chemali, 2019).

The profound psychological trauma caused by conflicts and political turmoil gives rise to a mental health crisis. The prevalence of mental health conditions such as depression, anxiety, and posttraumatic stress disorder has significantly increased. However, the availability of tools to effectively address these concerns remains limited. The economic consequences of political instability can result in periods of economic decline. The decline in national revenues has resulted in a decrease in financial allocations toward public health, thereby contributing to the degradation of services, obsolescence of infrastructure, and constraints on resources for innovation and advancement. The presence of enduring political instability has the potential to cultivate a sense of distrust throughout societies, which can extend to other institutions, including healthcare systems. Individuals may exhibit reluctance to seek medical attention, participate in immunization initiatives, or adhere to public health recommendations.

Opportunities for advancement

The convergence of traditional and modern elements within the Middle East is not solely a cultural occurrence but manifests in several domains, including healthcare. The region's fervent adoption of innovative technology signifies the onset of a paradigm-shifting period for providing patient care, advancing medical research, and enhancing health system efficacy. This discourse aims to explore a selection of innovative technologies and their prospective ramifications on healthcare within the Middle Eastern region.

AI's potential in diagnostics, predictive analysis, and treatment planning is vast. The utilization of AI has the potential to augment precision and expedite medical procedures, ranging from the examination of intricate medical imaging to the anticipation of disease outbreaks. Nations such as the UAE have already commenced efforts to incorporate AI into their healthcare infrastructures (Alhashmi et al., 2019). Telemedicine is a viable answer to the accessibility obstacles posed by the extensive landscapes and scattered people prevalent in numerous Middle Eastern nations. Virtual consultations have the potential to effectively address the geographical disparity between urban medical hubs and distant regions, hence facilitating equitable access to timely and high-quality healthcare services for those residing in these underserved areas. Wearable technology has emerged as a valuable tool for individuals to actively manage their health by providing real-time monitoring of critical statistics such as heart rate, blood sugar levels, and other relevant metrics. Wearable devices have demonstrated significant utility in the management of chronic illnesses such as diabetes, which exhibit a substantial prevalence within the given geographic area. Data integrity and security are paramount in the healthcare sector, with blockchain technology emerging as a potential solution. Blockchain technology can potentially provide viable solutions for patient data administration, including enhanced transparency, heightened security measures, and expedited access only for authorized individuals (Yaqoob, 2021). The medical manufacturing field is being significantly transformed by the advent of 3D printing technology, which can produce a wide range of products, including custom prosthetics and even biological tissues. In conflict-affected places, such as certain areas in the Middle East, the expeditious manufacturing of medical instruments and prosthetic devices can significantly alter the dynamics of the situation.

The field of genomic medicine has gained significant attention worldwide due to the growing focus on personalized therapy. In this context, the Middle East stands out as a region with distinct advantages, particularly in terms of its genetic databases. In nations such as Qatar and Saudi Arabia, academic institutions are actively engaging in the genomics field, aiming to comprehend genetic predispositions and customize medicinal therapies appropriately.

Robot-assisted surgery involves the utilization of robotic aids to perform minimally invasive procedures, hence enhancing surgical precision, mitigating the risk of human mistakes, and expediting the recovery process for patients. Several hospitals within the region are implementing this technology, enhancing the quality of surgical practices (Barkati, 2023).

In the context of medical teaching and patient rehabilitation, augmented reality and virtual reality technologies provide users with immersive experiences. One potential application of simulations is their use in surgical training, where they can be employed to replicate surgical procedures for training surgeons. Simulations can also be utilized to rehabilitate individuals facing mobility issues, aiding in their recovery process.

The Internet of Things in the healthcare sector can optimize hospital operations, monitor equipment, and enhance the delivery of timely patient care, particularly inside intensive care units. This is achieved through the interconnectivity of devices, enabling the sharing of real-time data.

The Middle East, characterized by its combination of abundant resources, ambitious endeavors, and openness to embracing innovative technologies, finds itself at a crucial crossroads. If these technologies are utilized efficiently, the region has the potential to bypass certain stages of healthcare development, establishing standards that can serve as benchmarks globally, all the while guaranteeing optimal healthcare for its population.

Collaboration with international institutions

Pursuing healthcare quality in the Middle East has progressively relied on partnerships with renowned international institutions. These collaborations not only enhance the medical standards of the region but also facilitate the sharing of knowledge, development of skills, and implementation of optimal approaches. This brief overview provides insight into the diverse ramifications of these collaborative endeavors.

The establishment of partnerships with international medical schools and institutes facilitates the development of Middle Eastern medical professionals through training programs conducted at globally renowned centers. These interactions facilitate the transmission of advanced knowledge and expertise, equipping a group of indigenous professionals to assume leadership roles in the region's healthcare sector.

Research partnerships frequently entail collaborative efforts in conducting research activities. In the Middle East, institutions can leverage the knowledge and resources of worldwide peers, enabling the execution of substantial research endeavors that have a profound effect, particularly in addressing the distinctive health concerns prevalent in the region.

Establishing cutting-edge medical facilities in the Middle East is frequently achieved through collaborations with prominent international healthcare organizations. An example of such collaborations can be observed in institutions like the Cleveland Clinic Abu Dhabi, which serves as a prime illustration of the integration of international benchmarks with local requirements.

Collaborative efforts frequently facilitate the provision of specialized medical services and treatments in the Middle East, hence addressing the dearth of such services in the region. Patients in the region have the opportunity to receive exceptional medical treatment without the need to go internationally due to the availability of sophisticated surgical procedures and specialized pediatric care.

International cooperation is crucial in promoting the acceptance of global healthcare standards and norms. Numerous regional hospitals actively pursue and successfully attain international accreditations through these collaborative relationships, guaranteeing that their services align with established worldwide standards.

International organizations, such as the WHO, frequently collaborate with governments in the Middle East on disease control and public health. These initiatives encompass a range of activities, including vaccination campaigns and disease surveillance, to promote adherence to optimal strategies and efficient allocation of resources.

Collaborations in healthcare policy and strategy extend beyond the scope of clinical care. Numerous Middle Eastern countries collaborate with international organizations and research institutions to formulate healthcare policies, strategies, and regulatory frameworks firmly rooted in empirical data and encompass a wealth of global expertise.

Partnerships in medical education encompass a wide range of collaborative endeavors. Numerous universities in the Middle East have established affiliations with esteemed foreign institutions, assuring that their curriculum, teaching methodology, and research possibilities align with global standards of excellence.

Technological Exchange: Collaborative efforts facilitate the Middle East in keeping pace with the newest advancements in healthcare technology, encompassing AI-based diagnostic tools and telemedicine solutions.

Role of public–private partnerships

Public–private partnerships (PPPs) have emerged as a fundamental element in developing the healthcare industry in the Middle East. As countries in the region contend with a range of complex issues, such as rapid population expansion, an ageing population, and the increasing burden of chronic illnesses, PPPs present a strategic method for bolstering and improving healthcare services. This analysis provides a more in-depth examination of the significance of these relationships within the region's healthcare landscape (Gharaee, 2023).

PPPs have proven highly advantageous for capital-intensive infrastructure development projects, particularly establishing hospitals, clinics, and specialized medical centers. The timely and practical construction of vital healthcare infrastructure is ensured by combining the private sector's investment and operational expertise with public monitoring and assistance.

Access and Reach: PPPs play a crucial role in improving healthcare access, especially in underdeveloped countries. The alignment of public intention and private efficiency might result in the creation of healthcare facilities in regions that may not provide immediate profitability but are crucial for the general public's well-being.

Technological Advancements: The private sector frequently demonstrates a greater capacity to embrace and promptly execute state-of-the-art medical technology. Public healthcare institutions can enhance their flexibility by utilizing PPPs. This enables them to include state-of-the-art diagnostic instruments, treatment methods, and health information systems.

The utilization of PPPs has the potential to enhance financial management and promote cost-efficiency within healthcare projects. The use of the private sector's proficiency in resource management, in conjunction with the extensive scale and breadth of governmental initiatives, has the potential to guarantee optimal value for each dollar expended.

In healthcare research and innovation, numerous private entities have prominent positions. By engaging in joint endeavors, public institutions can actively participate in this inventive endeavor, leading to the development of novel treatment regimens, the identification of new drugs, and the enhancement of patient outcomes.

The presence of global connections and comprehensive training frameworks characterizes the field of learning and development of skills in private healthcare companies. Through collaborative alliances, healthcare professionals in the public sector can avail themselves of these training possibilities, facilitating the improvement of their skills and the development of their capacities.

Service diversification refers to the ability of PPPs to facilitate the implementation of specialized medical services within public healthcare facilities. Establishing agreements between public institutions can effectively expand the range of services, encompassing advanced surgical techniques, specialized pediatric care, and unusual medical therapies.

Risk sharing is a crucial consideration in large-scale healthcare projects, as they inherently entail many types of hazards, ranging from financial to operational. PPPs facilitate the allocation of risks, enabling efficient resolution of difficulties without burdening either party excessively.

Policy and strategy alignment: PPPs frequently require ongoing discussions between stakeholders from the public and private sectors. The ongoing involvement guarantees that both sectors agree with their plans, policies, and objectives, resulting in a unified and all-encompassing approach to healthcare planning.

In conclusion, the Middle East actively strives to enhance its healthcare standards and achieve comprehensive health coverage. In this pursuit, PPPs have emerged as a highly effective instrument. By capitalizing on the respective strengths of both the public and private sectors and cultivating a culture of collaboration, PPPs can contribute to a more promising and improved future for the region's population.

Implications for policy

The significance of evidence-based decision-making is underscored by the distinctive difficulties and opportunities presented in the dynamic healthcare landscape of the Middle East. Within this particular setting, it becomes evident that research assumes a pivotal role, not only in the progression of medical science but also in the formulation of efficient and adaptable healthcare policy. The development and execution of healthcare policies within the specified territory. The comprehension of disease burden is facilitated by research, which aids in the identification of prevalent diseases as well as emergent health hazards. The Middle East is currently facing significant health difficulties, including diabetes, cardiovascular illnesses, and lifestyle-related disorders. Research has provided valuable insights into the scale and complexities of these issues. The evaluation of resource allocation can be informed by studies focusing on healthcare infrastructure, the availability of personnel, and the utilization of services. These studies can provide valuable insights for policymakers in determining the appropriate distribution of resources. This research has the potential to guarantee that places experiencing significant need are given appropriate attention and that financial resources are allocated in a manner that maximizes efficiency. The evaluation of existing policies and programs is of paramount importance, as it necessitates ongoing study to assess their performance. By utilizing feedback loops and outcome assessments, policymakers are able to analyze the effectiveness of policies and identify areas that may require adjustments. The integration of global best practices is vital, as research on healthcare practices and initiatives worldwide can yield invaluable insights. By examining both successful and unsuccessful cases from various regions, the Middle East has the opportunity to assimilate and tailor tactics relevant to its unique circumstances. The formulation of preventive healthcare policy can be influenced by research on behavioral patterns, societal trends, and risk factors. For example, gaining insight into individuals' food habits or exercise routines can provide valuable information for developing and implementing public health programs.

In order to effectively cater to the diverse cultural fabric of the Middle East, it is imperative to develop healthcare policies that demonstrate sensitivity and adaptability. Researching cultural views, patient preferences, and societal norms can contribute to aligning policies with the values and attitudes of the general population.

Anticipating Future concerns: Predictive research models can provide insights into forthcoming health concerns, encompassing prospective epidemics, demographic transitions, and the ramifications of climate change. Policies have the potential to adopt a proactive approach rather than being limited to a reactive stance. The research process frequently necessitates the active involvement of several stakeholders, ranging from healthcare practitioners and individuals receiving medical care to community leaders. This engagement guarantees that policies are firmly rooted in a wide range of perspectives and effectively address the comprehensive requirements of the community.

The integration of advanced technology in healthcare: Researching the latest medical technologies, digital health platforms, and telemedicine solutions can provide valuable insights for effectively incorporating these innovations into the healthcare system. This approach aims to maintain the Middle East's position as a leader in healthcare innovation.

Economic Considerations: The field of health economics study provides valuable insights into the cost-effectiveness of various treatments, interventions, and policies. These insights are crucial in guaranteeing financial viability and optimizing health outcomes while operating within budgetary limitations.

Ensuring evidence-based policymaking

The necessity for evidence-based decision-making in the healthcare sector has become increasingly prominent in a period characterized by swift progressions in medical knowledge and technological developments. In the context of the Middle East, a region characterized by its various demographics and distinct difficulties, adopting this strategy holds significant importance in pursuing healthcare quality. In order to ensure that healthcare policies in the Middle East are firmly grounded in evidence, the following strategies might be implemented:

Advocate for Rigorous Research: The fundamental basis for evidence-based policymaking is rooted in implementing rigorous and impartial research. Governments and institutions must allocate resources toward research efforts, establish partnerships with esteemed international research groups, and give precedence to studies that specifically target regional health concerns.

Propose the Establishment of Specialized Review Entities: Advocate for creating centralized entities tasked with the ongoing evaluation and integration of health research conducted at both global and regional levels. These entities can serve as intermediaries between the scientific community and policymakers, ensuring that policy decisions are based on the most up-to-date and relevant evidence.

Engaging diverse stakeholders is crucial in gathering evidence beyond mere numerical data. It involves various sources, including personal experiences, observations, and expert opinions. The involvement of healthcare professionals, patients, community leaders, and other stakeholders can facilitate a comprehensive comprehension of health-related matters and potential remedies.

Promote Data Sharing: Implement protocols to secure de-identified patient data sharing among hospitals, clinics, and research institutes. Extensive datasets possess significant value for academics engaged in analyzing illness trends, treatment outcomes, and the development of public health policies.

Enhance Training: Provide policymakers, public health authorities, and pertinent stakeholders with comprehensive training in evidence-based approaches to decision-making. This practice guarantees that individuals are capable of doing a thorough evaluation of research outcomes and effectively identifying their consequences for policy.

Implementing an open-access policy for research sponsored by public resources guarantees the availability of research findings to all relevant parties, thereby promoting transparency and accessibility. Establishing transparency in methodologies, data collection, and findings fosters confidence and enables well-informed policy determinations.

The concept of iterative policy design acknowledges that policies should not be considered immutable or fixed. The practice of evidence-based policymaking flourishes in a setting that allows for the continuous reassessment, improvement, and adjustment of policies in response to emerging research findings and evolving conditions.

Public engagement fosters open and informed discussions regarding healthcare research findings, enhancing acceptance and comprehension of evidence-based policies. Including public feedback can provide significant insights into the practical consequences of policy.

Intersectoral collaboration plays a crucial role in shaping health outcomes, as it recognizes that health is influenced by many factors that extend beyond the confines of healthcare institutions. These aspects encompass various domains, including education, environment, and economy. Evidence-based policymaking should incorporate collaborative efforts across several sectors to provide a comprehensive approach to health.

Balancing short-term needs with long-term goals

Due to its pressing demands and forward-thinking goals, the healthcare field frequently poses an intricate challenge for policymakers. In the Middle East, treating immediate healthcare demands and formulating enduring health plans is notably complex, owing to the region's rapid expansion, intricate socio-political dynamics, and distinct health concerns.

Developing a visionary healthcare blueprint is of utmost importance when addressing urgent difficulties and long-term goals. This may involve objectives such as attaining comprehensive health coverage, diminishing the prevalence of chronic diseases, or cultivating a robust healthcare research environment within the forthcoming decade or two.

The allocation of budgetary resources should be adaptable to meet both short-term healthcare requirements and the funding of long-term initiatives, such as research, infrastructure development, and preventative health programs.

Continuous Training and Skill Development: Although there is a demand for specialized healthcare workers capable of addressing present health concerns, allocating resources toward training healthcare practitioners in new medical disciplines is crucial to ensure the region remains equipped to tackle forthcoming challenges.

Public health campaigns play a crucial role in tackling prevailing public health concerns, such as the prevalence of smoking or sedentary behaviors. Raising awareness through these campaigns has the potential for substantial long-term advantages since they can effectively mitigate the burden of chronic diseases in the years to come.

Infrastructure development, including constructing advanced healthcare facilities and research centers, is a significant and enduring undertaking. These endeavors address the population's immediate healthcare requirements and accommodate future growth and progress in the field.

Data analytics can be crucial in prioritizing healthcare interventions, hence facilitating data-driven decision making. Policymakers can effectively allocate resources by understanding prevailing health trends and anticipating forthcoming concerns.

Collaborative partnerships can provide valuable opportunities for engagement with international health organizations and global health professionals. Such engagements can yield valuable insights into effectively handling current health crises while facilitating the acquisition of knowledge pertaining to creating long-term health strategies.

The formulation of policies should incorporate the perspectives and input of a wide range of stakeholders, ensuring that they effectively address the immediate issues of the community while also harmonizing with more significant health objectives.

Adopting a preventive approach in healthcare, which prioritizes regular health screenings, vaccines, and public health education, offers a more proactive strategy than a reactive one. This move not only addresses urgent health concerns but also has the potential to promote a healthier population and decrease healthcare costs in the long term.

The healthcare environment in the Middle East is undergoing significant changes, characterized by swift developments, ambitious goals, and distinct obstacles. This situation is of critical importance. As countries within the area see upward mobility in global health rankings and demonstrate a willingness to adopt innovative approaches, it becomes imperative to establish a well-defined and future-oriented agenda. This agenda should not only tackle immediate obstacles but also establish the necessary foundation for a healthcare future that is both sustainable and comprehensive. The following discourse presents a reflective analysis of the establishment of a visionary agenda.

The Middle East should prioritize the incorporation of digital health platforms, telemedicine, AI, and personalized medicine into its healthcare system to improve patient care and operational efficiency.

Universal health coverage refers to a system in which all individuals have access to essential health services without experiencing financial hardship. It is a concept that aims to ensure that everyone, regardless. An essential element of a healthcare system that is prepared for the future involves guaranteeing that all individuals, regardless of their socio-economic standing, are able to obtain high-quality healthcare services. In order to attain this ambitious yet crucial objective, it is imperative to allocate investments toward infrastructure development, training initiatives, and regulatory reforms.

The prioritization of healthcare research has the potential to position the Middle East as a prominent center for medical innovation on a worldwide scale. The prioritization of establishing globally renowned research institutes, cultivating partnerships with international health organizations, and allocating resources toward pioneering research endeavors should be regarded as crucial items on the agenda.

Adopting a preventive healthcare paradigm, which emphasizes early identification, health education, and lifestyle adjustments, can substantially alleviate the future burden of chronic diseases and enhance the overall health of the population.

Addressing Noncommunicable Diseases: Given the escalating incidence of ailments such as diabetes, cardiovascular diseases, and obesity, there exists a pressing necessity for all-encompassing approaches. These encompass public health initiatives, efforts to engage with communities, and collaborations involving several sectors.

The reinforcement of primary care facilities provides accessibility to healthcare, promotes cost-effectiveness, and effectively addresses health disorders during their early stages. The fundamental stratum of the healthcare system plays a crucial role in the holistic welfare of the population.

Workforce development is allocating resources toward the ongoing education and training of healthcare professionals, encompassing a range of roles from physicians and nurses to allied health workers. This strategic investment maintains the region's alignment with international healthcare standards and practices.

Recognizing mental health as a fundamental aspect of overall well-being is of utmost importance in implementing mental health initiatives. The prioritization of specialized infrastructure, professional development, and the destigmatization of mental health concerns should be integral components of the healthcare agenda.

Establishing a comprehensive framework for healthcare finance is crucial in promoting sustainability within the healthcare sector. This entails an examination of various models, such as the extension of health insurance, the implementation of PPPs, and the utilization of new funding methods. By examining these approaches, the financial viability of the healthcare system can be effectively secured.

The future of healthcare is predicated upon patient-centric approaches that prioritize customization. By integrating patient feedback, adopting shared decision-making practices, and prioritizing holistic treatment, healthcare in the Middle East has the potential to align more effectively with the needs and ambitions of its population.

Prioritizing areas of research

Given its varied population, complex socio-cultural fabric, and distinct health-related obstacles, the Middle East is currently at a crucial point in determining the direction of its healthcare development. Research plays a fundamental role in driving the advancement of evidence-based healthcare. However, in light of the extensive range of health issues and the constraints of available resources, it becomes crucial to establish priorities in the field of study.

Epidemiological studies play a fundamental role in comprehending the frequency and patterns of diseases. Priority should be given to doing research on noncommunicable diseases such as diabetes, cardiovascular disorders, and obesity, which have exhibited a significant rise in prevalence within the region.

The field of mental health has historically faced challenges in terms of inadequate attention and societal stigma. To address these issues, it is crucial to do comprehensive research that explores the prevalence and underlying causes of mental health disorders. Additionally, it is essential to develop intervention tactics that are specifically customized to the cultural peculiarities of the region in question.

The investigation of the environmental factors influencing health and their long-term consequences is of utmost importance, given the prevailing challenges such as water scarcity, air quality difficulties, and rising temperatures. The promise of telemedicine, electronic health records, and AI-driven diagnostic tools in transforming healthcare is extensive. Researching the effectiveness, obstacles, and potential for expansion can provide valuable insights for incorporating these interventions within the healthcare system. Examining the effectiveness, availability, and fairness of existing health systems can provide valuable insights for developing policy solutions. This includes examining various financial strategies, healthcare delivery techniques, and indicators related to patient satisfaction.

Maternal and Child Health encompasses research on various aspects, including prenatal care, delivery practices, pediatric disorders, and maternal health. These areas of study hold significant importance since they can greatly impact future generations' well-being and contribute to the reduction of mortality rates.

Behavioral and Societal Studies: Exploring patterns of behavior choices related to lifestyle and cultural values can inform the development of public health campaigns and interventions, hence enhancing their effectiveness and relevance to the general population.

By allocating resources and directing attention toward these specific study domains, the Middle East region has the potential to develop a healthcare system that is not solely responsive to existing difficulties but also anticipatory in mitigating potential future health catastrophes. The key to harnessing research for a healthier future lies in engaging in partnerships with worldwide research organizations, cultivating a thriving local research community, and effectively using research outcomes to inform policies and practices.

Incorporating patient and community perspectives

The Middle Eastern cultural framework, which is characterized by a strong emphasis on communal values and cultural traditions, significantly impacts healthcare perception and implementation. In order to foster a healthcare system that accurately aligns with the needs and ambitions of its constituents, it is imperative to integrate the viewpoints of patients and communities. This analysis examines the potential for the seamless integration of different perspectives into the healthcare fabric of the region.

Engaging patient advocacy organizations can significantly contribute to understanding patient needs, issues, and recommendations. These groups, which represent diverse health conditions and concerns, possess invaluable insights into the healthcare landscape. They function as intermediaries connecting the healthcare system and the community.

The acknowledgement of cultural beliefs, customs, and religious practices in healthcare decisions is crucial for ensuring that care is not only medically suitable but also culturally relevant, hence emphasizing the significance of cultural sensitivity in healthcare provision.

The establishment of community health forums facilitates an avenue for community members to express their health-related problems, exchange personal experiences, and offer constructive comments. This participatory approach engenders a sense of engagement among individuals and has the potential to inform healthcare policies and practices.

The provision of health education in local languages is a means of empowering individuals with knowledge and understanding. Providing health education in local languages and dialects, customized to the cultural subtleties of the respective location, enhances comprehension and compliance. Promoting collaborative decision-making fosters an environment in which patients assume an active role in the decision-making process regarding their healthcare. This approach entails engaging in discussions about various treatment alternatives and the associated risks and benefits, ultimately resulting in the provision of personalized and comprehensive care. Community health workers' utilization involves training persons within local communities, enabling them to serve as health workers. This approach ensures that healthcare programs are implemented with a deep comprehension of the unique dynamics and characteristics of the community in question. The process of co-creating health campaigns by engaging community leaders and members in the planning phase enhances the messages' cultural appropriateness, relatability, and potential effectiveness. Incorporating varied community viewpoints in study designs throughout health research endeavors might enhance the comprehensiveness and applicability of the findings. Including patients and the broader community is not solely a strategic decision but also an ethical imperative. In the Middle East, characterized by its diverse array of cultures, histories, and values, this comprehensive approach guarantees that the healthcare system is adept in clinical matters and sensitive to cultural nuances.

Aligning research with national and regional healthcare goals

A dynamic interplay of rapid innovations, long-standing traditions, and urgent health issues characterizes the healthcare scene in the Middle East. For research to generate significant and enduring effects, it must align with the healthcare objectives at both the national and regional levels. Herein lies an elucidation of the measures to guarantee this congruence inside the Middle Eastern milieu. The comprehension of national visions is a significant aspect of analyzing the strategic plans of various Middle Eastern countries, which often involve a wide range of industries, including healthcare. An example is the emphasis placed on a strong healthcare system and preventive health in Saudi Arabia's Vision 2030. Therefore, it is imperative for every research endeavor to align with the aims above (Rahman & Al-Borie, 2021).

The Middle East region encounters distinct health concerns, including an increasing prevalence of noncommunicable diseases, genetic problems resulting from consanguineous marriages, and specific infectious diseases. The research focus should be oriented toward comprehending, effectively addressing, and generating novel approaches to tackle the regional health concerns at hand.

Infrastructure and Capacity Building: The healthcare infrastructure in the region has experienced significant expansion. However, there is a need for research to investigate strategies for maximizing the efficiency of this infrastructure, improving healthcare delivery, and increasing its capacity. Such research can directly contribute to the achievement of national growth goals.

Collaborative Research Networks: In light of the common cultural and health attributes observed across numerous Middle Eastern nations, the establishment of regional collaborative research networks can facilitate the consolidation of resources, expertise, and optimal methodologies. This has the potential to accelerate the attainment of collective health goals.

Policy-driven research emphasizes the need to integrate research findings into developing and implementing effective health policies rather than existing in isolation. By effectively integrating research with policy requirements, nations can guarantee the implementation of decision-making processes that are grounded in empirical data and are consistent with their overarching health objectives.

The current emphasis on preventive health in national agendas necessitates a shift in research focus toward comprehending behavioral patterns societal ideas, and developing interventions that promote preventive health practices.

The Middle East's commitment to digitization and technological progress is reflected in its focus on health technology and innovation. Through research in areas such as health technologies, telemedicine, and AI-driven solutions, the region has the potential to become a global leader in health innovation.

Community engagement plays a crucial role in ensuring the alignment of research with the needs and viewpoints of the community, hence enhancing its relevance and application. Incorporating community members into the study process can provide valuable perspectives that link studies with the health needs of grassroots populations.

The Middle East faces distinctive environmental concerns, such as water scarcity and urbanization, which significantly affect sustainability and environmental health. Integrating environmental sustainability and health in research endeavors can effectively support achieving broader regional sustainability objectives.

Implementing continuous monitoring and feedback mechanisms is crucial in ensuring that continuing research remains aligned with the changing national and regional health objectives.

The alignment of research endeavors with national and regional objectives guarantees that the knowledge produced is academically enlightening and holds the potential for practical transformation. In the Middle East, a region now experiencing significant transformations in healthcare, this alignment has the potential to serve as a crucial element in facilitating research-based, objective-driven, and community-focused advancements in healthcare.

Conclusion and future agenda

The healthcare research environment in the Middle East exhibits distinctive obstacles but demonstrates remarkable expansion and prospects. Through the provision of ongoing governmental assistance, the implementation of infrastructure advancements, and the cultivation of research expertise, the region is steadily progressing toward establishing itself as a significant participant in global healthcare research. The convergence of tradition and innovation is paving the way for a prospective future in which the Middle East not only confronts its own obstacles but also provides valuable perspectives and resolutions to the international world.

The importance of healthcare research in the Middle East should not be underestimated. The linchpin serves as a crucial element that establishes a connection between the intricate interaction of cultural, economic, technological, and medical elements.

Research plays a crucial role in directing the region's pursuit of improved health outcomes, as it ensures that policies and agendas are specifically designed to address the distinctive challenges and potentials of the region.

A complex interaction between traditional characterizes the current state of healthcare research in the Middle East practices and innovative approaches, as well as a balance between addressing local healthcare needs and pursuing global healthcare goals. As the region persists in allocating resources and undergoing transformations in this domain, it holds the potential to make substantial contributions to the global body of healthcare knowledge and practices.

The ramifications of political instability for healthcare in the Middle East are significant. In addition to the immediate difficulties, the long-term consequences can extend beyond several generations, emphasizing the necessity of robust and adaptable healthcare systems and the significance of political stability and peace in promoting comprehensive well-being.

Research has a crucial role in providing direction for developing healthcare policies in the Middle East. By basing decisions on empirical data, evidence, and various perspectives from various stakeholders, the area may strategically navigate toward a healthcare ecosystem that is resilient, fair, and well-prepared for future problems.

By incorporating evidence-based approaches into the formulation of healthcare policies, the Middle East can enhance its strategies' effectiveness, efficiency, and alignment with the genuine healthcare requirements of its population. In the quest for a more salubrious future, empirical evidence is the guiding light illuminating the region's trajectory. The intricate interplay between immediate demands and future goals within the healthcare sector necessitates a sophisticated comprehension, proactive anticipation, and a steadfast dedication to the welfare of the general public. In the context of the Middle East's ambitions to become a prominent global healthcare center, achieving this equilibrium is not merely a preference but a need. By prioritizing long-term goals and objectives over short-term concerns, the area may lay the groundwork for a healthcare system characterized by adaptability and forward-thinking.

In brief, the Middle East's engagement with international institutions in healthcare demonstrates its dedication to providing optimal services to its population. These collaborations, founded on reciprocal esteem and shared objectives, can create a more optimistic and salubrious future for the area while enriching the worldwide fabric of medical knowledge and application.

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Information Technologies in Healthcare Industry Volume 4
Series Editor: Patricia Ordóñez de Pablos

Digital Healthcare in Asia and Gulf Region for Healthy Aging and More Inclusive Societies

Shaping Digital Future

Volume Editor
Patricia Ordóñez de Pablos
The University of Oviedo, Spain

Digital Healthcare in Asia and Gulf Region for Healthy Aging and More Inclusive Societies: Shaping Digital Future provides insight to the potential of advanced information technologies to build stronger healthcare systems, better quality healthcare services, and more resilient societies. The book covers two important regions: Gulf Region (Bahrein, Kuwait, Oman, Qatar, and UAE) and Asia, and explores how these countries develop policies for healthy aging and how digital tools can serve these goals.

This book delivers a collection of relevant, innovative research works on digital healthcare, with four main goals: (1) to cover two geographical regions (Asia and Gulf Region) with important advances in digital healthcare; (2) to present case studies in the field of IT and digital health during the pandemic and analyze the lessons from these studies; (3) to evaluate the latest advances in the field of digital healthcare (especially Artificial Intelligence [AI], Big Data, Blockchain, and 5G); and (4) to discuss implications for main stakeholders (patients, doctors, IT experts, directors, and policy managers) and recommendations for policy makers in these two regions and elsewhere.

The book is a valuable resource for researchers, clinicians, healthcare workers, policy makers and members of biomedical field who are interested to learn how digital technologies can help to avoid and solve a global disease dissemination.

Key Features

- Delivers relevant case studies and experiences on digital healthcare from Asia and Gulf Region, covering important advances in digital healthcare
- Provides recommendations for policy makers in Asia, the Gulf Region, and around the world
- Discusses implications for main stakeholders (i.e., patients, doctors, IT experts, directors, and policy managers) and recommendations for policy makers in these two regions and elsewhere
- Investigates the interplay of several important research areas (e.g., digital healthcare, 5G, AI, Big Data, and Blockchain) with an emphasis on healthy aging

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