Society 5.0: Realizing Next-Generation Healthcare

Zodwa Dlamini, Thabiso Victor Miya, Rodney Hull, Thulo Molefi, Richard Khanyile, and Jaira Ferreira de Vasconcellos

Abstract The concept of a new improved society known as Society 5.0 was first proposed in Japan in 2016 in the Japanese government's 5th basic plan for Science and Technology. This new improved smart society will rely on the use of new technologies such as artificial intelligence (AI), cloud computing, and the Internet of Things (IoT) to gather and analyze large amounts of data. This is then used to improve many aspects of society leading to sustainable development and the achievement of the United Nations (UN) sustainable development goals (SDGs). SDG-3 is to "Ensure healthy lives and promote well-being for all at all ages." This can be achieved in healthcare in society 5.0 through the use and integration of these new technologies. AI, machine learning (ML), and deep learning (DL) allow the creation of automated systems capable of learning, identifying features in patient data, and making a decision regarding diagnosis, prognosis, or treatment choices. AI can also be used to integrate large amounts of data to create digital twins of patients or populations to allow for more accurate modeling in many healthcare-related scenarios and implement precision medicine. Much of the data required to implement these technologies can be gathered through the IoT which allows personalized data regarding an individual's health, environment, and activity to be gathered by

Z. Dlamini (✉) · T. V. Miya · R. Hull
SAMRC Precision Oncology Research Unit (PORU), DSI/NRF SARChI Chair in Precision Oncology and Cancer Prevention (POCP), Pan African Cancer Research Institute (PACRI), University of Pretoria, Hatfield, Pretoria, South Africa
e-mail: zodwa.dlamini@up.ac.za; thabiso.miya@up.ac.za; rodney.hull@up.ac.za

T. Molefi · R. Khanyile
SAMRC Precision Oncology Research Unit (PORU), DSI/NRF SARChI Chair in Precision Oncology and Cancer Prevention (POCP), Pan African Cancer Research Institute (PACRI), University of Pretoria, Hatfield, Pretoria, South Africa

Department of Medical Oncology, Faculty of Health Sciences, Steve Biko Academic Hospital, University of Pretoria, Hatfield, Pretoria, South Africa
e-mail: thulo.molefi@up.ac.za; richard.khanyile@up.ac.za

J. F. de Vasconcellos
Department of Biology, James Madison University, Harrisonburg, VA, USA
e-mail: vasconjf@jmu.edu

Z. Dlamini (ed.), *Society 5.0 and Next Generation Healthcare*,
https://doi.org/10.1007/978-3-031-36461-7_1

smart connected devices through the Internet. To be successful, this digital information must be used in such a way as to result in the merging of cyberspace and physical space through the integration of cyber-physical systems. All these new developments will require and drive a revolutionary change in the healthcare ecosystem. The use of these new healthcare technologies also presents governments and healthcare systems with new legal issues, ethical questions, and fears surrounding the restructuring of the healthcare ecosystem. Additionally, the implementation of these new technologies is complicated by the current worldwide energy crisis. The solutions to these problems are already being sought. Technologies such as AI, IoT, and digital twins are being used to design and manage newer smarter electricity grids and assist in the introduction of new energy sources, while Blockchain technology can possibly provide a solution to issues surrounding the responsible storage and management of data. The use of these technologies to implement healthcare based on the concept of Society 5.0 promises to give individuals a healthier, longer, and more productive life.

Keywords Society 5.0 · Healthcare · UN SDG3 · AI · IoT · Cloud computing · Digital twins · Blockchain technology · Safety · Privacy · Energy crisis · Rights · Security · Ethics

1 Introduction

1.1 Industrial Revolution

From the beginning of civilization, technology has been recognized by humankind as a tool for the advancement of society. This has been greatly accelerated since the First Industrial Revolution (Industry 1.0) (Mourtzis et al. 2022) (Fig. 1). The First Industrial Revolution began around the 1780s and comprised mechanical power production using fossil fuels, water, and steam. The Second Industrial Revolution (Industry 2.0) followed in the 1870s whereby manufacturers preferred electrical energy for mass production and assembly lines (Mourtzis et al. 2022). The Third Industrial Revolution (Industry 3.0) followed in the 1970s and was characterized by the integration of automation into the production industries using Information Technology (IT) and electronics (Fig. 1). The fourth industrial revolution (Industry 4.0) is defined by the use of artificial intelligence (AI), cloud computing, and the Internet of Things (IoT) to facilitate Cyber-Physical Systems (CPS) (Fig. 1). These systems serve as a real-time interface between physical and virtual worlds (Mourtzis 2016; Elmaraghy et al. 2021). Industry 4.0 signifies the rapid change in technology, social patterns, industries, and processes in the recent decade. Advancements of innovative technologies such as AI, big data analytics, and digital twins under Industry 4.0 framework have improved product and service quality as well as production efficiency (Rüßmann et al. 2015).

However, Industry 4.0 framework has limitations because engineers mainly focused on technological advancements in production and manufacturing systems

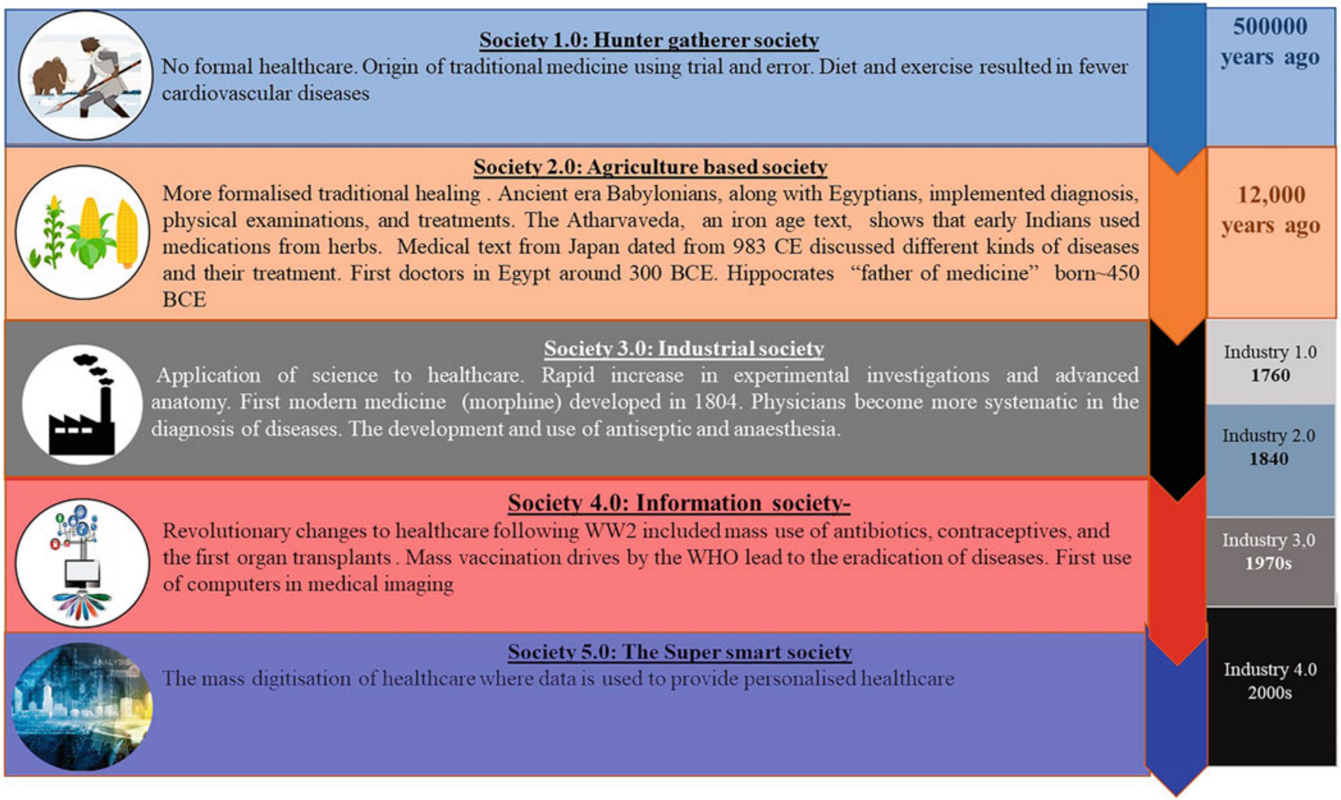

Fig. 1 Dateline of societies and industrial revolutions. The progression from society 1.0 to Society 5.0 is depicted alongside the changes in healthcare seen in each society

and networks (Xu et al. 2021). The engineers prioritized industrial efficiency and flexibility over worker welfare and industrial sustainability (Xu et al. 2021). Thus, the emergence of a new era of industrial transformation is soon. The new era will enable engineers to optimize current technologies for the benefit of humankind and social factories (Mourtzis et al. 2022). Countries such as Japan, the United States, and the European Union have already made a move toward the human-centric era of industrial transformation (Mourtzis et al. 2022). This new era is called Industry 5.0, and it also extends to Society 5.0. It is important to note that Industry 4.0 is still an ongoing technological transformation, and that Society 5.0 and Industry 5.0 are still under preparation (Mourtzis et al. 2022). This has created misconception that Industry 5.0 may not be recognized as an independent industrial revolution (Mourtzis et al. 2022).

1.2 What Is Society 5.0?

The Government of Japan launched the Society 5.0 (super-smart society) concept in April of 2016 (Fukuda 2020). Society 5.0 can be described as a novel society in the fifth stage which follows the hunting society, the agrarian society, the industrial society, and the information society as shown in Fig. 1 above (Fukuda 2020). This concept is aimed at creating a human-centered society whereby services and products will be easily accessible. Consequently, this will reduce social and economic gaps so that all people can lead prosperous lives (Fukuda 2020). Society 5.0 is the same as Industry 4.0; however, it takes a further step by portraying a data-driven society (super-smart society) and economy. Furthermore, it focuses on individual capabilities and needs (Mavrodieva and Shaw 2020). Society 5.0 conceptualizes a merge between the cyberspace and the physical space (real world) to effectively gather more personal and precise data, thereby improving value creation and problem solving (Fukuyama 2018). In addition, large quantities of data that have been collected over the years require time and human resources to analyze a job that could be performed rapidly using AI. This data could also be transformed into easy formats that can be understood and used by humans in various industries and social services (Mavrodieva and Shaw 2020). The Society 5.0 concept became an official policy in Japan when it was included in their 2016 Fifth Science and Technology Basic Plan for the first time (Mavrodieva and Shaw 2020). Parties involved pledged that this concept will significantly support the United Nations Sustainable Development Goals (UN-SDGs) and also create a sustainable, inclusive, and human-centered society (Mavrodieva and Shaw 2020). A sustainable society organizes itself to better the autonomy and the quality of life for its citizens. It also aspires to the common welfare economy, and it does not compromise its future opportunities. Sustainability is comprised of society, environment, and economy. Society is an important base among the three (Fig. 2).

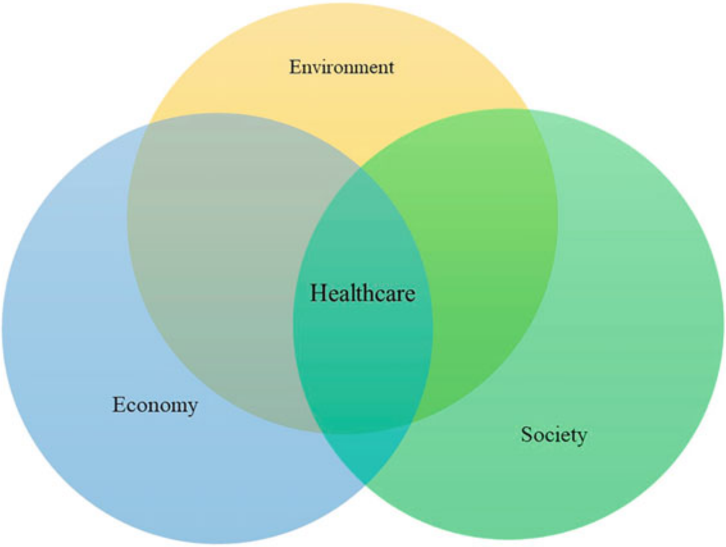

Fig. 2 Three bases that form sustainability. Adapted from Aquilani et al. (2020)

The UN-SDGs are aimed at achieving collective progress through co-operation between citizens and governments to eradicate social inequality (Gustiana et al. 2019). Since the establishment of these goals, many nations have directed their investments and research toward these sustainability goals (Fukuda 2020; Hayashi et al. 2017; Záklasník and Putnová 2019). In this case, sustainable development is conceptualized from its planning, use of aspiring technology and infrastructure developments, to attain both an improved environment and efficient industrialization (Aquilani et al. 2020).

Japan plans to spread the Society 5.0 concept worldwide by working with other nations to achieve its implementation (Mavrodieva and Shaw 2020). The Society 5.0 concept could change the way society functions in all areas of life. This concept will positively impact the economy of Japan as well as other countries and also help in tackling numerous social challenges (Fukuyama 2018). Society 5.0 will impact all aspects of life, but it is mainly focused on nine social and economic sector, namely, healthcare, finance, energy, agriculture and food security, disaster prevention, cities and regions, logistics, manufacturing, and public services (Fig. 3) (Mavrodieva and Shaw 2020). When it comes to healthcare, Society 5.0 aims to focus on using AI-based medical services such as telemedicine, prevention and individualized healthcare services, as well as access to personalized life-stage data (Mavrodieva and Shaw 2020).

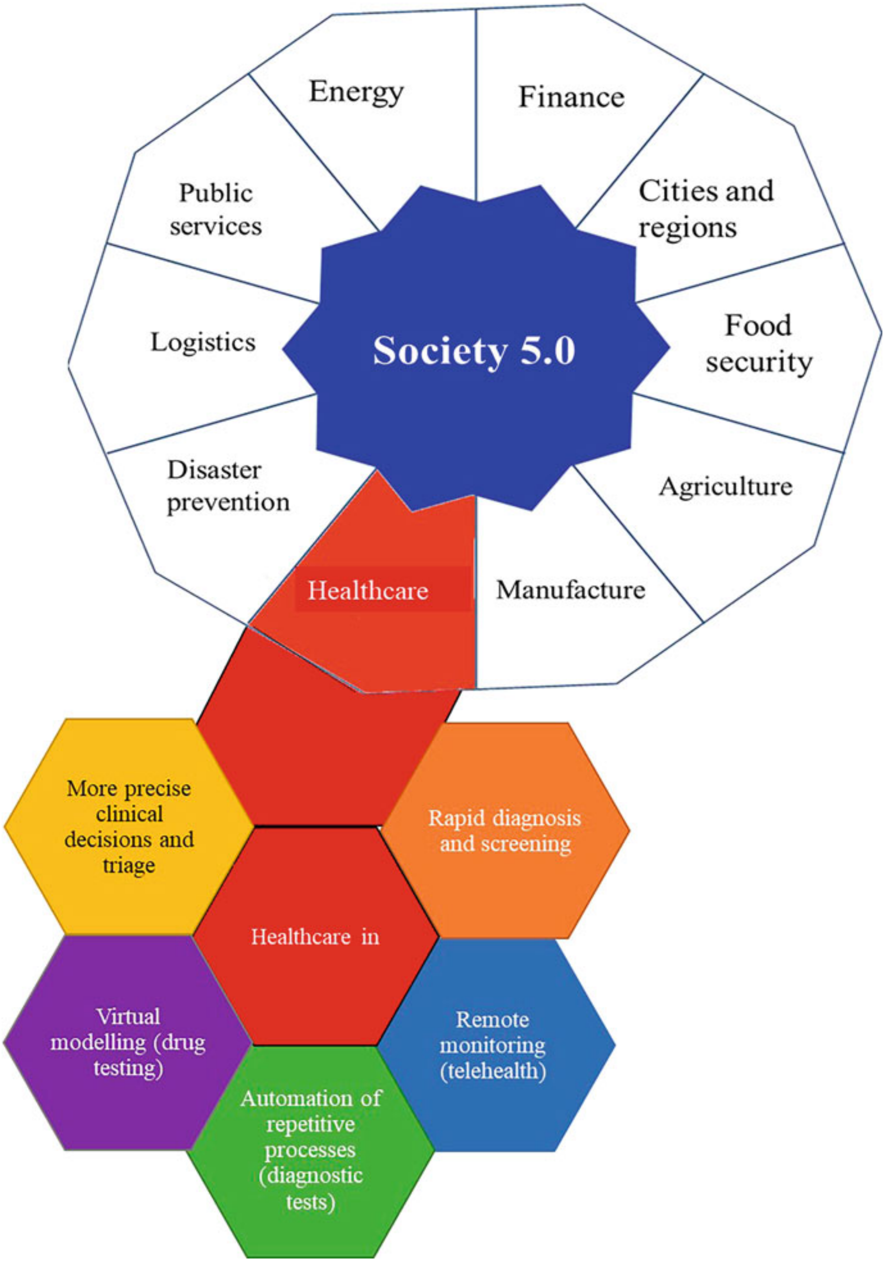

Fig. 3 Smart solutions facilitated by Society 5.0. Adapted from Narvaez Rojas et al. (2021)

2 Digital Transformation in Healthcare

Digital transformation has revolutionized many industries, especially the healthcare industry (Natakusumah et al. 2022). In the healthcare industry, technology enables individuals to live healthier, more productive, and longer lives. For instance, telemedicine was accessed by over one million people in 2015. In 2021, this number increased to 12 million people (Natakusumah et al. 2022). Thus, technology has allowed patients to access quality healthcare even in remote areas (Tortorella et al. 2022). According to Maiurova et al. (2022), Pappas et al. (2018), Ricciardi et al. (2019), and Natakusumah et al. (2022), several other health technologies such as Blockchain, IoT, robotics, and AI have been developed and applied in this industry. Different companies view technology as an asset and not just infrastructure. To this effect, data analysis can be used to improve access to quality healthcare and also lower healthcare costs (Natakusumah et al. 2022). Utilization of health technologies allows consumers (patients) to easily access information regarding diseases, treatment options, and also the ability to choose healthcare facilities that aligns with their needs (Maiurova et al. 2022; Natakusumah et al. 2022; Pappas et al. 2018; Ricciardi et al. 2019). Realization of the benefits of using health technologies has led to more healthcare providers adopting digital transformation into their management systems (Natakusumah et al. 2022). In turn, this has led to provision of improved quality healthcare (Natakusumah et al. 2022).

2.1 Health Technologies

Health technologies have constantly changed since the inception of medicine. Furthermore, increasing knowledge and diagnosis, treatments, rehabilitations, and prevention possibilities have changed healthcare systems (Ricciardi et al. 2019). Digitalization ranging from the use of computers to remotely monitor patients, electronic medical devices, as well as the computer-assisted visualization and decision support systems has affected many areas of healthcare systems (Ricciardi et al. 2019). Digital transformation involves the introduction of new digital information and communication technologies, as well as new corresponding processes into the healthcare industry. Digitalization can lead to changes and innovations in health technologies and delivery, thus impacting healthcare and health systems (Ricciardi et al. 2019).

2.2 Artificial Intelligence (AI)

AI and other related technologies are increasingly common in society and business and are now increasingly applied in the healthcare industry (Davenport and Kalakota

2019). In addition, these technologies can potentially transform multiple aspects of patient care as well as in the administration process within healthcare institutions and pharmaceutical companies (Davenport and Kalakota 2019). AI can be described as the intelligence of machines instead of the intelligence of humans or other living organisms (Minsky 1961; Weng et al. 2001). It also refers to occasions whereby machines can simulate human minds in learning and analysis. Thus, AI can be involved in problem solving, and this kind of intelligence is also called machine learning (ML) (Huang et al. 2015). AI technologies are relevant to the healthcare industry; however, their specific supported tasks and processes differ widely. For instance, ML is commonly applied in precision medicine whereby it is used to identify the correct treatment protocols to use and predict the potential successes of these treatments in a patient (Lee et al. 2018). Most ML and precision medicine applications need a training dataset with a known outcome (e.g., disease). This is also known as supervised learning (Davenport and Kalakota 2019). An even more complex form of ML exists, which is comprised of neural network. Neural networks are discreet organized units of algorithms that act together in a hierarchical manner to mimic the human brain. This technology has been available since the 1960s and is used for categorization applications (Sordo 2002). For example, it can be used to determine whether a patient will develop a certain disease over a certain period of time (Davenport and Kalakota 2019). Lastly, deep learning (DL) and neural network models (with many feature levels and variables) are the most complex ML technologies. There are potentially thousands of hidden features in these models. DL is commonly applied in healthcare to recognize potentially malignant lesions in radiological images (Fakoor et al. 2013). Furthermore, DL is also applied in radiomics, or the detection of features that are clinically relevant in medical images (Vial et al. 2018). Radiomics and DL are mostly found in oncology-related image analysis. Thus, integration can potentially be used to increase diagnostic accuracy compared to previous generations of image analysis. Image analysis can also be automated using computer-aided detection (CAD) tools (Davenport and Kalakota 2019).

AI applications in drug discovery can increase access to medicine and improve the experience of patients, their families together with healthcare workers, and everyone involved in the healthcare system. Access to affordable safe, effective, and affordable medicine is a fundamental human right. To try and attain universal human rights and improve the lives of all the earth's inhabitants, the UN-SDGs need to be achieved by the year 2030. Goal 3 talks about "Ensuring healthy lives and promoting well-being for all at all ages," and particularly, Goal 3.8 seeks to "Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all" (United Nations 2015). However, more than half of the people living in low- and middle-income countries (LMICs) do not have access to essential medicines for a variety of reasons including the high cost of medicines and poor healthcare infrastructure. New medicines are unaffordable for the majority of the population living in LMICs, while at the same time these countries have 75% of the world's poor, accounting for the majority of the global disease burden (Stevens and Huys 2017). Therefore, leveraging the advantages of AI, its increased speed coupled with reduced cost of drug development, will be paramount if we are to attain Goal 3 of the UN-SDGs.

Although AI has a potential to transform the health industry, it has several technical challenges lying ahead (Yu et al. 2018). For instance, as ML-based algorithms rely on the presence of large amounts of high-quality training data, data that represent target patient population need to be cautiously compiled (Yu et al. 2018). Furthermore, proper data curation is needed for overseeing heterogeneous data. In addition, acquiring patients' gold standards requires health professionals to individually review clinical notes (Yu et al. 2018). This process is expensive on a population scale. Numerous high-performing ML models often create results that are hard to interpret by unassisted people. Additional AI challenges are economic, social, and legal (Yu et al. 2018). However, the greatest challenge to AI is ensuring its adoption into daily clinical practice (Davenport and Kalakota 2019).

2.3 Digital Twins

Digital twins are become an integral part of the digital transformation (Saracco 2019). This transformation is facilitated by the IoT and advanced data analytics (Fuller et al. 2020). A digital twin can be described as a virtual representation of a physical entity which can be utilized in the design phase to analyze, predict, and simulate behavior and store evolving descriptive data (Saracco 2019). A digital twin environment enables fast analysis and real-time decision-making using accurate analytics. Digital twin technology can be applied in various industries including healthcare, manufacturing, smart cities, etc. (Saracco 2019). In healthcare, digital twins can be used to simulate the effects of certain drugs on humans. It can also be used in planning and performing surgery (Gahlot et al. 2018). Furthermore, a digital twin enables doctors, researchers, and healthcare facilities to simulate environments that are specific to their needs in real-time or for future developments or utilizations. Integration of AI algorithms into digital twin technology enables smarter decisions and predictions (Saracco 2019). The use of digital twins for healthcare is still in its initial stages, but its potential is wide, for example, in hospital management where it can be used to improve the assignment of beds, management of large-scale wards, and hospital administration. This technology can also be used for predictive maintenance and repair of medical equipment (Saracco 2019). Lastly, digital twin technology together with AI can be used to make life saving choices that are based on real-time and historical information (El Saddik 2018; Ross 2016).

Digital twins can provide scientific data to address the current gaps in environmental policies and in the long term, reach the UN-SDG-3 goals with regards to maternal newborn and child deaths. Evidence shows that endocrine disruptor chemicals (EDCs) have a substantial impact on most if not all of the omics (Bornman et al. 2017; Singh et al. 2021). All this information is contained within the patient's digital twin (Voigt et al. 2021; Walsh et al. 2020).

Digital twins, new knowledge, the combining of data, and AI integration are set to transform the healthcare industry (Kamel Boulos and Zhang 2021). However, this technology faces several challenges. In particular, digital twins have common issues and challenges with big data analytics and modern AI (Guidance 2021). These challenges include issues with data quality, availability, sharing, interoperability, and integration (Kamel Boulos and Zhang 2021). Other issues include intellectual property concerns, data security and privacy, reproducibility and transparency, and AI biasness (Kamel Boulos and Zhang 2021).

2.4 Internet of Things (IoT)

The convergence of medicine and information technologies has changed the healthcare industry into a more advanced system with efficient and accurate services (Bhatt et al. 2017). Such convergence is achieved through the Internet of Things (IoT). This technology has great impact on healthcare and medicine applications (Bhatt et al. 2017). IoT technology comprises of a physical devices network together with embedded sensors, software, devices, and network connectivity for the exchange of data (Zanella et al. 2014). Thus, the IoT can be described as a method of connecting devices/objects like sensors and smart phones to the Internet to link the devices together (Kortuem et al. 2009). Linking of these devices/objects enables novel communication forms between the devices, system components, and humans (Kortuem et al. 2009). IoT technology integrates common domains such as embedded systems, control systems and automation, as well as wireless sensor networks for device-to-device communication through the Internet (Da Xu et al. 2014). The dependence of the healthcare industry on IoT technology is increasing healthcare access and quality, as well as reducing healthcare cost (Frederix 2009). Personalized healthcare is based on a patient's exclusive biological, behavioral, and social characteristics (Bhatt et al. 2017). In turn, this leads to a reduction in healthcare costs. Support services can target early disease detection and result in homecare instead of clinical care (Bhatt et al. 2017). IoT technology can provide health personalization serves while also preserving digital identification of all patients (Bhatt et al. 2017). Categorization of IoT regarding personalized healthcare systems is comprised of clinical care and remote monitoring (Simonov et al. 2008). Applications of IoT technology in the healthcare industry include:

- Heart rate monitoring, which involved independent monitoring of biometrics of each patient through specific threshold settings. Additionally, vital signs like blood pressure and weight are also remotely monitored through integrated supplementary devices (Bourge et al. 2008).
- Monitoring of aging individuals in hospitals using IoT ultrasound-based technologies as personalized home healthcare solutions tracking and locating patients' activities. In addition, emergency calls can be managed in a cost actual system for wide area communication interface. This system can be a wearable sensor which

is waterproof and can be programmed to send out reports including position signals to the ultrasound receiver (Bhatt et al. 2017).

IoT can make significant contributions to support the implementation of the SDGs with regards to social and environmental aspects. Pay-as-you-go and low-cost IoT can be potential solutions to achieve SDGs by 2030 (López-Vargas et al. 2020). IoT can help achieve sustainable and stronger development, and allows the opportunity for economical and human development while the impact in developing countries must not be overlooked (Rahim 2017). Developing countries are shown to be ideal for IoT innovation, since it can support economic growth, and contribute to cultural, environmental, and social development (Barro et al. 2018). IoT development has allowed for the management and monitoring of renewable energy systems that improve the electrical access (Biggs et al. 2016; Ramanathan et al. 2017). IoT has the potential to predict and minimize the destruction caused by natural disasters (Pelc and Koderman 2018) like tsunamis and earthquakes (Biggs et al. 2016), thereby avoiding serious injuries and also saving lives. The benefits of IoT fall into the UN SDGs. Specifically, IoT implements SDG goals 3 (Good Health and Well-Being), 6 (Clean Water and Sanitation), 14 (Life Below Water), 15 (Life on Land), and 17 (Partnership for the Goals). Goal 3 aims for good health and well-being. IoT allows the capturing of data on all devices and allows model predictions to improve health and well-being. Sensors of various devices will upload the data that can be analyzed. Goal 6 aims to ensure clean water and sanitation. IoT will allow the monitoring and management of water, sanitation, and electrical systems and technologies (Biggs et al. 2016; Ramanathan et al. 2017; United Nation ESCAP 2018). IoT will allow all the data captured by sensors to be analyzed and will provide reliable information about the water resources state, usage, wastewater generation, and treatment (Krishnamurthi et al. 2020). IoT can be used to improve life on land and in water (Goal 14–15) by allowing predictive modeling based on the capturing of data by various devices. Actions can be taken to avoid catastrophic events and improve the health of all living organisms on land or in the water. IoT will also facilitate the growth of partnerships worldwide to increase the collaboration between people, science, and technology (Goal 17). IoT allows all data to be captured and stored and will be accessible across the Internet. This will allow world contribution based on data analysis, and the partnerships will allow improved ideas for healthcare and healthcare management.

IoT services and devices will drive the healthcare industry toward novel generation of efficient services while also saving lives and time with greater accuracy in terms of the predictions and recommendations that can be made (Bhatt et al. 2017). However, IoT technology has several challenges that lie ahead. The standard web services are the most adopted Internet technology (Bhatt et al. 2017). Wireless healthcare systems need functionalities, and this is challenging in the future of the Internet. New technologies and standards need to address security and privacy features for the users, network, applications, and data in the future (Bhatt et al. 2017). In general, the most challenging issues facing IoT technology include settling on security, device capabilities, merging the gaps between sensors, individuals, safety, and fabrication (Bhatt et al. 2017).

2.5 Blockchain Technology

The healthcare industry is constantly trying to keep up with modern technologies and apply them to improve healthcare services to patients (Dasaklis et al. 2018). In this regard, Blockchain technology has already been exploited in several areas of healthcare, including; healthcare data management, privacy, or interoperability (Esposito et al. 2018; Mettler 2016). Blockchain can be described as a secure digital ledger that records and stores transactions (Rathore et al. 2020). The ledger is kept in a decentralized network of nodes which are formed using cryptographic processes computed by all network users (Zhao et al. 2017). Blockchain ledger storage capacity is very dependable because it creates digital signatures and hash chains using consensus algorithms. To this extent, Blockchain technology offers numerous services such as security, traceability, integrity, and nonrepudiation. It does all this while also storing all the data in a public decentralized and privacy-protecting manner (Zhao et al. 2017).

Since Blockchain is decentralized and constantly updated, it presents many opportunities for the healthcare industry (Mettler 2016). For example, Blockchain can be applied in medical treatment processes like in chronic diseases or elderly care (Mettler 2016). The following are some of the key features of Blockchain that can benefit the healthcare industry (Yaqoob et al. 2022):

– **Health data accuracy**

  Since Blockchain maintains updated, traceable, secure records, it can be used to store the entire medical history of a patient (Wang et al. 2018). In turn, this allows healthcare workers to provide timely, efficient, and accurate treatments to the patient. Importantly, all data stored on the Blockchain network are transparent, immutable, traceable, and tamper-proof (Agbo et al. 2019).

– **Health data interoperability**

  Interoperability can be defined as the ability to exchange data between systems manufactured by different companies. A lot of e-health/medical records (EHR/EMR) are products created from different technical specifications, functional capabilities, and clinical technologies (Reisman 2017; Khan et al. 2014). These different systems prevent creation and sharing of data in single format. Thus, Blockchain can be used to store this data while also allowing it to be accessed and utilized by various healthcare institutions (Yaqoob et al. 2022).

– **Health data security**

  A significant number of healthcare institutions still use centralized infrastructures for storing and processing digital medical records (Redka 2019). However, these systems are outdated and vulnerable to cyberattacks and fraud (Redka 2019). Furthermore, these digital medical records can also be lost through events such as natural disasters. Thus, Blockchain can be used to prevent data mishandling, fraud, or theft using its immutability feature (Yaqoob et al. 2022).

In terms of UN-SDG (Goal 3) “Good health and well-being,” Blockchain technology could facilitate change in relation to sustainability that can impact health, medication, and humanitarian aid supply and distribution (Hughes et al. 2019). Developing countries still face challenges in relation to the integrity of basic food products and medical supplies. Furthermore, logistical management and enforcement across geographical diversity and linguistic barriers are also major challenges in developing counties (Hughes et al. 2019). Blockchain technology can help solve these challenges by enabling parties to ship and monitor the lifecycle of health products by using its transactional integrity and immutability features. This will in turn improve health and well-being of the citizens (Hughes et al. 2019).

Other Blockchain applications in the healthcare sector include global health data sharing, improved healthcare data audit, improved drug traceability, clinical trials and precision medicine, and health insurance coverage optimization (Yaqoob et al. 2022). Although Blockchain has numerous potential applications in the healthcare industry, it has challenges that still need to be addressed before it can be completely integrated into the healthcare system (Yaqoob et al. 2022). These challenges include scalability, interoperability, regulatory uncertainty, tokenization, irreversibility and quantum computing, and ensuring healthcare data accuracy (Yaqoob et al. 2022).

2.6 Health Informatics

Developing nations are facing serious challenges in delivering healthcare to their citizens (Norris 2002). These challenges are induced by factors such as the rising number of elderly citizens who need care, increasing costs of medical technologies, social, and economic changes that prevent governments from funding healthcare appropriately among others (Norris 2002). The aforementioned challenges increase costs and decrease equity of access to healthcare (Norris 2002). As such, governments and established healthcare organizations are increasingly interested in the ability of Health Informatics to save human lives, time, and money (Shukla et al. 2014). Health Informatics can be described as the science of how health information is collected, analyzed, and used to improve health and healthcare (Fridsma 2018). It involves devices, resources, and methods needed to improve processes for acquiring, recovering, storing, and usage of health and biomedicine information (Oyelade et al. 2015). Health Informatics can be applied in various areas of healthcare, including clinical care, health services administration, medical research and as well as training (Shukla et al. 2014). Health Informatics uses tools such as computers, information and communication systems, clinical procedures, as well as formal medical vocabularies (Oyelade et al. 2015). It also facilitates storage and retrieval of health information in an organized and more precise manner compared to the ability of patients to recall details such as allergies and medications details (Oyelade et al.

2015). This is a critical issue for the patients. Inaccurate or insufficient health information from patients can lead to severe drug side effects (Oyelade et al. 2015). Thus, provision of accurate health information is particularly important. Health Information permits joined-up care, whereby various health departments, e.g., surgery, radiology, laboratory, administration, or account sections, are interlinked (Oyelade et al. 2015). In turn, this facilitates reduction of efforts duplication and also allows processes to be much quicker (Oyelade et al. 2015). Lastly, computerized Health Informatics guidelines enable health professionals and patients to make better decisions. Thus, high-quality treatments and prescriptions can be sustained (Oyelade et al. 2015).

Advanced technology and AI-empowered tools are important in the efficient integration of informatics in Society 5.0. Furthermore, equitable health through Society 5.0 cannot be achieved without the integration of UN-SDGs. The UN-SDGs specific to this subsection are Goal 3 (good health and well-being of a society), Goal 8 (a healthy society with decent work driving economic growth), Goal 10 (reduced inequalities in healthcare systems will have a positive impact on overall reduced inequalities), Goal 11 (preventative medicine through health informatics and exposome data can aid built sustainable cities and communities), Goal 13 (considering climate changes can aid in building sustainable development), Goal 15 (investing in environmental health and education is key in a healthy and wealthy society), and Goal 17 (societies should build partnerships in achieving a smart and healthy society).

Health Informatics can potentially play a key role in the management and delivery of healthcare services in developed and less developed nations (Oak 2007). It can also facilitate the evaluation of healthcare needs of citizens and also the effectiveness and coverage assessment of healthcare programs (Oak 2007). Like other modern and innovative technologies, Health Informatics faces several challenges. These challenges include confidentiality and privacy breaching caused by inadequate security monitoring during data transmission or storage. Another problem is the substandard diagnostic quality of images generated by computers e.g., dermatological or X-ray images. Medical errors can also be induced by insufficiently constructed computerized care methods, insufficient protocols for novel computer-assisted practices, or unavailable or failed technology, among others. Finally, there are issues surrounding the privacy of electronic health records.

2.7 Merging Cyberspace with Physical Space to Improve Women's Health in Low- and Middle-Income Countries

Cyberspace can be described as a digital space where real-world data are collected and analyzed by computers to create various solutions (Deguchi et al. 2020). This is where virtual life or events are converted into applicable information. On the other hand, physical space refers to the real world. Thus, merging these two entities will permit a smooth flow from the physical world to the cyberspace and vice versa (Deguchi et al. 2020). We envision a society where scientific and technological innovations culminate into the merging of cyberspace and physical space (Deguchi et al. 2020). In turn, this merge can be used to improve women's health and early detection of diseases where strategies and services are decentralized so that all women lead higher-quality lives (Deguchi et al. 2020). This would require a system where women's health information is collected and processed, with the results being applied in a real-world setting, be that rural or urban (Adel 2022). With the current advancement in technology, access to smartphones and other intelligent devices, such ideas should have long been implemented even in low- and middle-income countries (LMICs). Women, in this age of advanced healthcare services, should not be dying from preventable diseases such as cervical cancer. Besides advancements in primary cervical cancer prevention strategies such as HPV vaccines, the disease also has premalignant lesions, which when identified early can be destroyed and their development into invasive cancer can be prevented. These shortcomings are due to failure to merge cyberspace and physical space. Applying Society 5.0 to a subunit of society such as a village or a suburb in a Metropolitan city can provide solutions in an LMIC setting (Deguchi et al. 2020).

In Society 5.0, healthcare social issues surrounding screening programs can be addressed by connecting these programs and using technology to integrate big data, the IoT, and AI to develop digital and physical infrastructure for services such as cervical cancer screening (Narvaez Rojas et al. 2021). Implementation of programs to improve women's health in LMICs faces several challenges. For instance, the current red tape hinders progress in developing services such as building an intersector information integration architecture and striking a balance between the protection and access to personal information. Existing national and district regulations need to be eased so that innovation can be successful (Deguchi et al. 2020). Rural areas in these LMICs currently have little identifiable data management systems, and these should be established. On the other hand, the urbanized part of the LMICs has some regions with data management administered both privately and publicly, and these should be consolidated and coordinated, resulting in the building of intersector information integration architecture (Deguchi et al. 2020).

2.8 Integration of Cyber-Physical Systems in the Advancement of Society 5.0 Healthcare Management

The focal point of Industry 4.0 is efficient and optimal industrial production and data management. It is comprised of cyber-physical systems (CPS) in which the physical and digital worlds are intertwined by the industrial IoT. The aim is to create smart machines/factories that can be utilized in various sectors including health (Adebayo et al. 2019; Popov et al. 2022). Future technological advancements have sparked the idea of smart or intelligent hospitals. Integration of AI technologies for the processing of high volumes of patient information through big data systems to allow prompt decision-making is essential for the new concepts adapted to Society 5.0 (Lindén and Björkman 2014). Most of the technologies used for monitoring patients' health status rely on embedded systems. The use of glucose/heart rate/ blood pressure monitors, magnetic resonance imaging (MRI), computerized tomography (CT) scans, positron emission tomography (PET) scans, etc. has advanced medical diagnostics and monitoring (Lindén and Björkman 2014). These systems permit remote monitoring of patients and facilitate prompt diagnosis and treatment decisions. However, future technologies continue to advance toward nano and smart technologies, including microchips. Society 5.0 is expected to bridge the gap between cyberspace and physical space. To achieve this, Society 5.0 will facilitate the realization of modern smart technologies through the integration of AI algorithms which facilitates big data analytics, IoT, metaverse, robotics, digital twining, Blockchain, and networks-on-chip (NoC) for the optimization of personalized medicine.

The UN-SDG Goals 3, 9, and 10 aim to reduce premature mortality by ensuring good health and promoting well-being (Chotchoungchatchai et al. 2020). These can be achieved by the development of smart industrial innovation and infrastructure which will facilitate the implementation of virtual realities which will reduce the use of invasive health management protocols. The development and availability of infrastructure will reduce global inequalities and ensure global healthcare competitiveness.

The ability to tailor-make healthcare management systems according to specific disease/personalized treatment comes with its pros and cons. Medical CPSs are vulnerable to cyber-attacks making cyber security a big concern. These attacks could be due to terrorism or organized crime. The safety of these technologies must be assured by the development of high confidence, authenticated software that can guarantee security of medical CPS. Software systems handle big data and also guarantee confidentiality and safe keeping of these data while providing easy access to the user are critical. If this data falls into the wrong hands, it could compromise the patient' health, making them vulnerable to discrimination, possible bodily harm, and abuse. The performance of real time applications requires low fault latency to prevent delays that could disturb the operational cycle of medical CPS. This could lead to poor data sharing and consequently affect timeous patient diagnosis and treatment. Lastly, safety for the use of the medical CPS should be assured by issuing operational certificates. The process of approving and validating these devices should be cost-effective, thus ensuring that these devices are distributed to provide required services (Lee et al. 2011). Currently, the cost-effectiveness of medical CPS devices such as robotic systems is not certain as it is difficult to prove that the benefits of robotic surgery outweigh that of traditional open and laparoscopic surgery (Chiu et al. 2019).

2.9 Society 5.0 and Quality Multidisciplinary Care of Malignant Solid Tumors in Low- and Middle-Income Settings

Noncommunicable diseases have overtaken infections as the leading causes of mortality globally, including in LMICs. Noncommunicable diseases include trauma, cardiometabolic conditions, and cancer. The average life expectancy of adults in LMICs is less than 70 years, and cancer is the second most common cause of death in adults between the ages of 40 and 60 years. Around 70% of deaths due to cancer occur in LMICs. Breast, colon, prostate, gastric, cervix, uterine, ovarian, hepatocellular, skin, thyroid, and adenocarcinoma of the pancreas are among the most commonly diagnosed malignancies in both LMICs and high-income countries (HICs). The majority of LMICs are not able to provide quality curative or end of life care in oncological services. This is due to the advanced stage of the tumor at initial presentation, shortage of expertise, protracted diagnostic work-up, and limited access to advanced imaging and treatment (Akinyemiju et al. 2022; Hunter et al. 2022; Kenner et al. 2021; Raghupathi and Raghupathi 2020; Sharma et al. 2022). Among the goals contained in the Millennium Development Goals (MDG), UN-SDGs, and Vision 2030 include the provision of quality healthcare in all countries of the world (Araújo 2020; Van Tulder et al. 2021; Rahman and Qattan 2021). UN-SDGs and Vision 2030 specifically include prevention of cancer and improving access to early diagnosis and effective treatment. Technological and computational advances introduced from Society 1.0 to Society 4.0 have led to an even bigger gap in the quality of oncological care between LMICs and HICs. Society 5.0 intends to utilize modern technological development and digitalization to achieve borderless and classless personalized quality healthcare services.

All 17 UN-SDGs are interlinked and support promotion of well-being and healthy lifestyle (Budhathoki et al. 2017; Rahman and Qattan 2021). The pillars of UN-SDG 3 are prevention of diseases, timeous access to quality treatment, and reduction of out-of-pocket expenses (Kruk et al. 2018). Preventative strategies which are contained in UN-SDG 3 are access to clean water, sanitation, health education, immunization, and screening program (Budhathoki et al. 2017). The UN-SDG 3 envisaged that all governments in the world will provide leadership and encourage active participation by private companies including multinationals in programs to improve the health of every individual. Society 5.0, SDG, and Vision 2030 do not have programs which are offered based on the income level of a country. Little has been achieved due to lack of political will, competing needs, tough economic situation, and minimal involvement of the private sector. Collaboration between governments and the private sector would make the technological advances affordable and available in LMICs which would lead to an improvement in the quality of oncological services. Like smart cities, smart oncological services would be safe, convenient, and cheap. Quality multidisciplinary care of malignant solid tumors will allow UN-SDG 3 to be achieved by providing the needed care to improve the health and well-being of the patient.

Implementation of Society 5.0 faces several challenges. It requires investment in the infrastructure which may not be affordable in LMICs. Available health information system, computer network programs, and the Internet speed may not be adequate to support the rollout of the envisaged Society 5.0 programs. Most of the training, development, and testing of the program would happen in HICs which is different from the situation in LMICs. Society 5.0 also threatens confidentiality and autonomy. A fault in the settings of some of the devices may lead to complications. New technology, including robotic surgery or endoscopy may have a negative impact on the teaching and training of future generations of healthcare practitioners.

2.10 Technological Innovations and the Advancement of Preventive Healthcare for Society 5.0

The merits of preventive medicine in LMICs public health systems can never be overemphasized. Paradoxically, their health system capabilities are the most compromised and overstretched due to restricted financial and other resources in these regions. Technological advances that have capitalized on Industry 4.0 are mainly biased toward therapeutics and diagnostics where disease has already established itself. This approach is untenable in LMICs. Although these developments have revolutionized healthcare and dramatically improved the quality of life, these achievements have impacted a fraction of the population in wealthy countries. Therefore, there is a challenge for practical health technological solutions to prevent onset and progression of diseases that is inclusive of most of the poor and disadvantaged populations particularly in LMICs. This is in line with the core principle of the UN-SDGs which is premised on leaving no one behind, and the UN-SDG 3 calls for universal health coverage and health and well-being for all ages. As countries embrace this inclusive vision and collectively aspire for a better society by the year 2030 through the 2030 global agenda, there is a great demand to ensure that everyone succeeds in implementing the UN-SDGs—by using new approaches and tools that help identify and address health inequity in all its forms (World Health Organization 2016). One such approach is to optimize preventive medicine through technology for all vulnerable populations with the additional outcome of easing the burden to the healthcare systems for LMICs.

AI-based applications and sensor technologies for biomarker detection in biofluids face several challenges. High financial cost associated with the use of AI-based applications is a major challenge, which will have a negative impact on people from rural communities and low-income backgrounds who do not have medical aid insurance and do not have access to smart devices or the Internet. Furthermore, the majority of countries in Africa are exposed to poverty and do not have adequate healthcare facilities and infrastructures to support AI-based preventative medicine practices. As a result, there is an urgent need for more cost-effective solutions to tackle this issue. Furthermore, there is also a severe lack of research funding in Africa, which requires immediate attention from first-world research and innovation funding stakeholders to assist African medical doctors, scientists, and computer and software engineers in developing simple and cost-effective AI-based healthcare software. A major issue with these advancements is the huge financial burden associated with purchasing wearable technologies and smart clothing, which will negatively impact individuals from low- and middle-income households. Furthermore, the majority of people from poor socioeconomic backgrounds, residing in rural areas do not have access to the Internet and wi-fi which is a challenge since wearable technology and smart clothing heavily rely on connectivity networks to communicate the monitored physiological parameters to the user (Ahsan et al. 2022; Chen et al. 2016; Ching and Singh 2016; Mokhtarian and Tang 2013).

2.11 Transformation of the Healthcare Ecosystem in the Era of Society 5.0

The term ecosystem is often used in healthcare to refer to a community consisting of patient and doctor, and all satellite figures involved in the patient care in and out of hospital. The COVID-19 pandemic has given us new lessons and changed the definition of the normal worldwide. Some lessons may be temporary; however, groundwork changes in our approach to healthcare ecosystem design will be necessary to assist in handling challenges of future catastrophes. The healthcare ecosystem is mainly comprised of value creation formula, customer value proposition, as well as partner network. These elements are driven by four business model pillars, namely, management, information, financing, and human resources. The use of AI in healthcare promises to revolutionize healthcare structural reforms in terms of robustness, agility, and accuracy. Digitization of healthcare systems is occurring on several fronts such as cloud-based technology, Blockchain technology, and medical IoT. Many of these health technologies offer a hope to improve access to healthcare to under-resourced communities as well as provide quick often real-time access to patient health data for quick real-time clinical decisions but are not without limitations. Whereas some of these limitations are purely technical, others are born from the risk of compromised patient privacy. These healthcare technologies further improve the wave of precision medicine in the long run. The health ecosystem digital era requires innovations that advance diagnosis and treatment, especially in hospital-based patient care usually by reducing error (Wadhwa 2020). Furthermore, numerous innovations are also required to ensure continuous care through the facilitation of off-site patient management. This can be achieved through telemedicine by reducing waste in the delivery system (Wadhwa 2020). By partnering with individuals to support self-management, digital innovation will positively impact on the social determinants of health (Serbanati et al. 2011).

The healthcare ecosystem transformation should be aligned to the UN-SDG "Good health and well-being" by working toward removing barriers of access to healthcare using modern technology. An effective healthcare ecosystem will increase access to screening, early diagnosis, and improved accessibility of high-quality medicinal treatment. It can also assist to improve the community and patient's knowledge of cancer, lifestyle modifications, quality of life benefits, and diet. The improved healthcare ecosystem as previously mentioned, can be used to ensure that the patients focus on cure rather than the disease itself. At the same time, access without affordability will be meaningless, and thus, cost-effective funding strategies should also be pursued through collaborative partnerships especially targeting the low-income communities.

Digital technologies provide advantages that are associated with the possibility of remote access to many medical services, and in the last decade have led to the rapid spread of digital medicine. Furthermore, there are several negative factors that have emerged through the diverse use of digital technologies in medicine. These technologies may cause serious harm to the life and health of people and induce significant damage to the society (Mirskikh et al. 2021).

3 Barriers to the Implementation of Society 5.0-Based Healthcare the Energy Crisis

One of the greatest barriers to the implementation of the technologies required for the development of a new smart healthcare system is the lack of resources required to implement them. These include lack of storage capacity, cloud computing capacity, computational power, raw materials for the manufacture of the required hardware, expertise for the design and manufacture of both hardware and software, and perhaps most crucially energy. The implementation of Society 5.0 will require a reliable supply of energy (Kheirinejad et al. 2022). The current energy crisis was already a barrier back when the concept of Society 5.0 was proposed; however, recent events such as the COVID-19 pandemic and the Ukraine–Russia war have exacerbated the crisis. This crisis has important negative implication for healthcare as a whole, since clean, sustainable, and affordable energy plays a crucial role in advancing health (World Health Organization 2022). This clean energy is another SDG, SDG-7, and this goal is aimed at supporting sources of clean energy such as hydro solar, geothermal, sea waves, and wind. In this way, it hopes to decrease the generation of harmful by-products such as CO_2, thereby helping to achieve another SDG-SDG-13 Climate change action (Nam-Chol and Kim 2019; Zengin et al. 2021). The energy crisis is therefore a barrier to not only Society 5.0 but also to attaining the SDGs. This is in part due to an affordability crisis, where the generation of electricity is too expensive (Gabel 2022). This has resulted in some SDGs "going backwards" as families have been pushed into poverty (SDG-1) (International Energy Agency 2023). The affordability of energy will have a direct impact on industries required to support healthcare such as the pharmaceutical industry. The rising cost of energy may force companies to increase the cost of drugs, remove cheaper generic drugs, and limit the availability of drugs (Hawkins 2022; Stewart 2023). The effect that the dwindling global energy supply on the implementation and use of digital healthcare technologies has is vast. These technologies require a constant supply of power with the IoT requiring power to collect, filter, and transmit data, with some studies indicating that IoT devices can waste up to 30% of the energy they consume (Shah et al. 2022). AI obviously requires energy to run the vast cloud computing networks required to provide the necessary computing power. These concerns in powering the use of Blockchain technology require large amounts of electricity for the validation of all Blockchain-based transactions or records (Schinckus 2022). These technologies have arisen despite most of these technologies using minimal energy. The energy crisis has impacted the entire world; however, these effects are even more damaging and far reaching in LMICs, resulting in these countries not being able to implement these new technologies which are so badly needed in these countries. Even without the energy crisis, it is common in many LMICs for there to be no power or an unreliable or limited supply in many villages and other establishments (Jamal 2015). LMCs would also suffer the most from effects such as increased electricity prices (Stewart 2023).

Many of these concerns can be partially negated by improved energy management, the use and integration of renewable energy systems, and the cautious implementation of these new technologies, so as to not overwhelm the energy supply (Schinckus 2022). An addition to this, it has been shown that many of these new digital technologies can also provide solutions to the energy crisis. AI, the IoT, and digital twinning have allowed for the management, monitoring, and consumption of energy resources (Sifat et al. 2022; Nandury and Begum 2015). Smart grids (SG) would improve the flow of data and electricity within the electricity system networks (ESN) and allow for the replacement of conventional fossil fuel-rich grid with distributed energy resources (DER) (Kumar et al. 2020). These SGs can be designed with the aid of AI and modeled using digital twin in order to assess them before they are implemented (Sifat et al. 2022). IoT can also assist in the implementation of SGs, through the more efficient transfer of power to smart devices and buildings, thus reducing consumption (Pan et al. 2015).

4 Ethical and Legal Challenges in Society 5.0 Next-Generation Healthcare

Many of these technologies that are the basis for the development of healthcare into a Society 5.0 are not without their own problems and issues. These issues include bias, ethical issues ranging from the violation of basic human rights, such as privacy and patient autonomy, to issues of cost and availability to issues around mistrust on the use of these new technologies to issues surrounding racial and cultural bias (Myers et al. 2008). Many of these issues stem from the basic requirement that personalized medicine in Society 5.0 requires vast amounts of information to be gathered about everyone. This immediately brings the privacy of the individual into question. The rampant and unregulated information gathering through remote sensors, the IoT, and cloud computing means that information can be gathered without patient permission. It also means that an excess of information can be gathered, some of it with no bearing on patient health and well-being. This information can then be sold, known as data brokerage, to commercial companies. This data can also be used for purposes other than health, such as criminal investigations, in a process known as function creep (Xafis 2015). The intensive gathering and analysis of data can also lead to overdiagnosis. Overdiagnoses can lead to a population of hypochondriacs, unnecessary treatment, and unnecessary burden on a healthcare system (Kale and Korenstein 2018). The removal of patient autonomy is another real concern, where there is a fear that the use of AI will result in the patient becoming disempowered regarding the choices made about their own health. AI is by far the most controversial of these modern technologies, with many fears surrounding how untrustworthy or error prone an AI can be. To concerns regarding an AI not being able to adjust its analysis to suit diverse cultures or being prejudiced by learning from race specific data. The lack of transparency when it comes to AI, leading it to be dubbed a black box is an issue of concern for many clinicians. This leads to them not trusting the treatment decisions suggested by the AI because they do not know how it has reached these decisions (Guo et al. 2021). AI is also influenced by the adage garbage in garbage out, where the AI is only as good as the data it is given, or the training data used to teach it. This also highlights problems with the technologies used to gather information in that it is not clear how accurate many of these devices are (Clayson et al. 2021). This coupled with software upgrades and different operating systems or software on different devices leading to data corruption and the extent of mistrust in much of this information becomes clear. Mobile or remote devices also need to be calibrated using an external device. In LMICS, qualified technicians and calibration devices may be in short supply or only available in urban centers. There is also a valid fear that all this information, especially omics information, can be used by AI and digital twin technology for nefarious purposes. These include population control, segregation, and in the most extreme cases genocide (Poghosyan 2020). This all leads to the requirement of new laws and regulatory bodies to control and police these modern technologies, although this raises the question of responsibility. When these technologies fail and harm is caused to a patient, who will be held responsible. This is especially relevant when it comes to AI as the AI itself cannot be held responsible. However, should the manufacturers or designers be blamed or the endpoint users? Additionally, what if the error was caused by what the AI had learnt from other data or previous use. In this case, the manufacturer or designer may not be to blame, while the endpoint user may not possess the knowledge to understand or realize the failure of the system. The best solution may be a list of responsibility for every step of the usage of these new technologies (Dignum 2019). Companies involved in the development of these innovative technologies need to adopt ethical culture and indorse ethical leadership. Figure 4 below shows steps that companies need to take in order to develop an ethical structure (Tzafestas 2018). Despite all these problems, the promise these modern technologies offer cannot be ignored, and

Fig. 4 Steps that regulatory bodies need to take in order to develop new ethical standards in healthcare. Adapted from Tzafestas (2018)

as such, careful deliberation and planning must take place to ensure their ethical design and application for all stakeholders.

5 Conclusion

The implementation of healthcare in Society 5.0 aims to improve the longevity of individuals and allow them to exist with longer periods of good health. It will accomplish this by minimizing the incidence and severity of disease and optimizing medical expenses. Finally, this future healthcare system will provide care over the course of the life of all individuals without prejudice or bias. In order to accomplish this, it will use current and future technologies which are a defining feature of Society 5.0 (Fig. 5). This book will discuss the use of these technologies in the implantation of healthcare in Society 5.0.

The first chapter will discuss the use of Intelligent Bioinformatics in healthcare and outline how it can be used to analyze data to contribute to personalized medicine and healthcare. The second chapter will discuss the care of patients with malignant

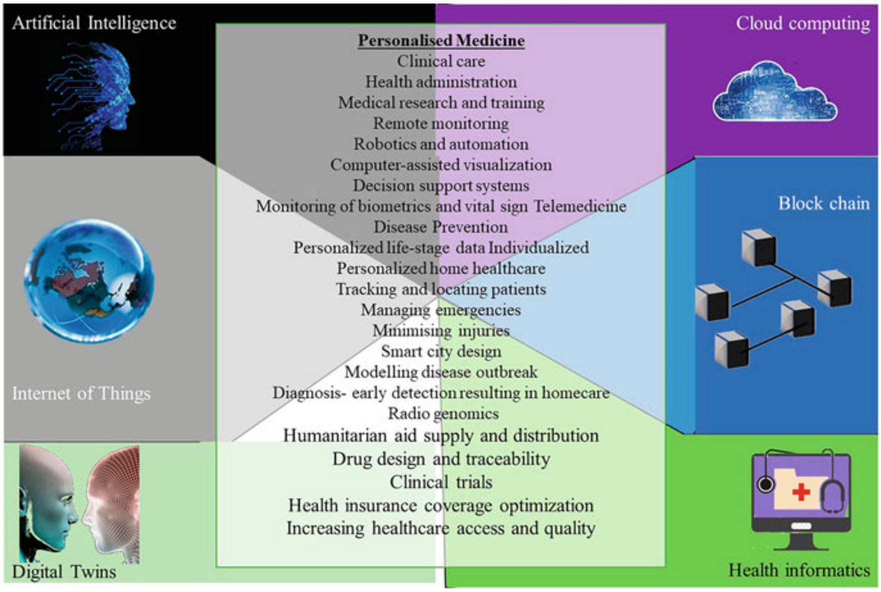

Fig. 5 A summary of healthcare in Society 5.0 detailing the different technologies that will transform healthcare and what they hope to achieve. Compiled by Rodney Hull

solid tumors in LMIC settings in Society 5.0. Specifically, it will discuss the implementation of multidisciplinary care in this setting and how the lives of these cancer patients in LMICs will be improved through the use of Society 5.0-based healthcare. The book will then move on to discuss the use of technology in a smart society to prevent diseases through the implementation of smarter knowledge-based screening and surveillance. It will then discuss the role played by the IoT in gathering the substantial amounts of personalized accurate and up-to-date data required for personalized healthcare. Moreover, it will discuss a specific example of the use of healthcare based on Society 5.0 in the screening, prevention, and management of cervical cancer in an LMIC healthcare setting followed by the use of AI in enhancing drug discovery for a human-centered health system. In addition, it will discuss the role played by digital twins in modeling patients, treatments, and public health in Society 5.0. The following chapter will discuss the implementation of integrated Cyber-Physical Systems in healthcare. This will be followed by a chapter on how the healthcare ecosystem will be revolutionized by the introduction of these technologies and how the interconnected roles and activities of patients, healthcare providers, policy makers, and administrators will be to make healthcare more affordable, robust, and efficient. Data security, privacy, and protection are major concerns for the implementation of this smart, data-driven healthcare system, and the next chapter will discuss the use of Blockchain technology in protecting this data and ensuring the continued safe development and use of large amounts of data to personalized medicine. Finally, this book will discuss the barriers and problems facing the use of these new technologies. These include legal and ethical issues, issues surrounding the privacy and protection of information as well as issues concerning the safety and trust in these new technologies. These problems can and must be solved for the implementation of healthcare in Society 5.0 since the advantages of this smart information-based, personalized healthcare system would outweigh any drawbacks if it is implemented responsibly.

The digital transformation of healthcare allows for easier access to healthcare as well as giving patients the ability to be more in control of their own healthcare leading to a system that is driven by healthcare professionals and patients working together. It is hoped that this book will provide a comprehensive introduction to the various aspects of healthcare in Society 5.0 and will demonstrate the importance of the future implementation of Society 5.0.

References

Adebayo AO, Chaubey MS, Numbu LP (2019) Industry 4.0: the fourth industrial revolution and how it relates to the application of internet of things (IoT). J Multidiscip Eng Sci Stud 5:2477–2482

Adel A (2022) Future of industry 5.0 in society: human-centric solutions, challenges and prospective research areas. J Cloud Comput 11:1–15

Agbo CC, Mahmoud QH, Eklund JM (2019) Blockchain technology in healthcare: a systematic review. Healthcare 7(2):56

Ahsan M, Teay SH, Sayem ASM, Albarbar A (2022) Smart clothing framework for health monitoring applications. Signals 3:113–145

Akinyemiju T, Ogunsina K, Gupta A, Liu I, Braithwaite D, Hiatt RA (2022) A socio-ecological framework for cancer prevention in low and middle-income countries. Front Public Health 10: 884678

Aquilani B, Piccarozzi M, Abbate T, Codini A (2020) The role of open innovation and value co-creation in the challenging transition from industry 4.0 to society 5.0: toward a theoretical framework. Sustainability 12:8943

Araújo NMF (2020) Impact of the fourth industrial revolution on the health sector: a qualitative study. Healthc Inform Res 26:328–334

Barro P, Degila J, Zennaro M, Wamba S (2018) Towards smart and sustainable future cities based on Internet of things for developing countries: what approach for Africa? EAI Endorsed Trans Internet Things 4

Bhatt C, Dey N, Ashour AS (2017) Internet of things and big data technologies for next generation healthcare. Springer, New York

Biggs P, Garrity J, Lasalle C, Polomska A (2016) Harnessing the Internet of Things for global development

Bornman MS, Aneck-Hahn NH, De Jager C, Wagenaar GM, Bouwman H, Barnhoorn IE, Patrick SM, Vandenberg LN, Kortenkamp A, Blumberg B (2017) Endocrine disruptors and health effects in Africa: a call for action. Environ Health Perspect 125:085005

Bourge RC, Abraham WT, Adamson PB, Aaron MF, Aranda JM, Magalski A, Zile MR, Smith AL, Smart FW, O'Shaughnessy MA (2008) Randomized controlled trial of an implantable continuous hemodynamic monitor in patients with advanced heart failure: the COMPASS-HF study. J Am Coll Cardiol 51:1073–1079

Budhathoki SS, Pokharel PK, Good S, Limbu S, Bhattachan M, Osborne RH (2017) The potential of health literacy to address the health related UN sustainable development goal 3 (SDG3) in Nepal: a rapid review. BMC Health Serv Res 17:1–13

Chen M, Ma Y, Song J, Lai C-F, Hu B (2016) Smart clothing: connecting human with clouds and big data for sustainable health monitoring. Mobile Netw Appl 21:825–845
Ching KW, Singh MM (2016) Wearable technology devices security and privacy vulnerability analysis. Int J Netw Secur Appl 8:19–30
Chiu C-C, Hsu W-T, Choi JJ, Galm B, Lee M-TG, Chang C-N, Liu C-YC, Lee C-C (2019) Comparison of outcome and cost between the open, laparoscopic, and robotic surgical treatments for colon cancer: a propensity score-matched analysis using nationwide hospital record database. Surg Endosc 33:3757–3765
Chotchoungchatchai S, Marshall AI, Witthayapipopsakul W, Panichkriangkrai W, Patcharanarumol W, Tangcharoensathien V (2020) Primary health care and sustainable development goals. Bull World Health Organ 98:792
Clayson PE, Brush CJ, Hajcak G (2021) Data quality and reliability metrics for event-related potentials (ERPs): the utility of subject-level reliability. Int J Psychophysiol 165:121–136
Da Xu L, He W, Li S (2014) Internet of things in industries: a survey. IEEE Trans Ind Inform 10: 2233–2243
Dasaklis TK, Casino F, Patsakis C (2018) Blockchain meets smart health: towards next generation healthcare services. In: 2018 9th International conference on information, intelligence, systems and applications (IISA). IEEE, pp 1–8
Davenport T, Kalakota R (2019) The potential for artificial intelligence in healthcare. Future Healthc J 6:94
Deguchi A, Hirai C, Matsuoka H, Nakano T, Oshima K, Tai M, Tani S (2020) What is society 5.0. Society 5:1–23
Dignum V (2019) Responsible artificial intelligence: how to develop and use AI in a responsible way. Springer Nature
El Saddik A (2018) Digital twins: the convergence of multimedia technologies. IEEE Multimed 25: 87–92
Elmaraghy H, Monostori L, Schuh G, Elmaraghy W (2021) Evolution and future of manufacturing systems. CIRP Ann 70:635–658
Esposito C, De Santis A, Tortora G, Chang H, Choo K-KR (2018) Blockchain: a panacea for healthcare cloud-based data security and privacy? IEEE Cloud Comput 5:31–37
Fakoor R, Ladhak F, Nazi A, Huber M (2013) Using deep learning to enhance cancer diagnosis and classification. In: Proceedings of the international conference on machine learning, 2013. ACM, New York, pp 3937–3949
Frederix I (2009) Internet of things and radio frequency identification in care taking, facts and privacy challenges. In: 1st international conference on wireless communication, vehicular technology, information theory and Aerospace & Electronic Systems Technology, 2009. IEEE, pp 319–323
Fridsma DB (2018) Health informatics: a required skill for 21st century clinicians. British Medical Journal Publishing Group
Fukuda K (2020) Science, technology and innovation ecosystem transformation toward society 5.0. Int J Prod Econ 220:107460
Fukuyama M (2018) Society 5.0: aiming for a new human-centered society. Japan Spotlight 27:47–50
Fuller A, Fan Z, Day C, Barlow C (2020) Digital twin: enabling technologies, challenges and open research. IEEE Access 8:108952–108971
Gabel E (2022) The energy crisis is reshaping power sector policies worldwide [Online]. S&P Global Commodity Insights. https://www.spglobal.com/commodityinsights/en/ci/research-analysis/the-energy-crisis-is-reshaping-power-sector-policies-worldwide.html. Accessed 25 November 2023
Gahlot S, Reddy S, Kumar D (2018) Review of smart health monitoring approaches with survey analysis and proposed framework. IEEE Internet Things J 6:2116–2127
Guidance W (2021) Ethics and governance of artificial intelligence for health. World Health Organization, Geneva

Guo Z-J, Zhang Q, Liu Y, Bai Z-M, Qiang L, Li H-Y, Zhang Y-H, Chi H-W, Men M, Xu Q (2021) Preliminary investigation and imaging analysis of early lung cancer screening among petroleum workers in North China. Cancer Investig 39:321–332

Gustiana I, Wahyuni W, Hasti N (2019) Society 5.0: optimization of socio-technical system in poverty reduction. In: IOP Conference Series: Materials Science and Engineering. IOP Publishing, Bristol, UK, p 022019

Hawkins L (2022) The impact of the energy crisis on pharma [online]. Pharma iQ. https://www.pharma-iq.com/business-development/news/the-impact-of-the-energy-crisis-on-pharma. Accessed 18 January 2023

Hayashi H, Sasajima H, Takayanagi Y, Kanamaru H (2017) International standardization for smarter society in the field of measurement, control and automation. In: 2017 56th Annual Conference of the Society of Instrument and Control Engineers of Japan (SICE). IEEE, Geneva, pp 263–266

Huang G, Huang G-B, Song S, You K (2015) Trends in extreme learning machines: a review. Neural Netw 61:32–48

Hughes L, Dwivedi YK, Misra SK, Rana NP, Raghavan V, Akella V (2019) Blockchain research, practice and policy: applications, benefits, limitations, emerging research themes and research agenda. Int J Inf Manag 49:114–129

Hunter B, Hindocha S, Lee R (2022) The role of artificial intelligence in early cancer diagnosis. Cancers 14:1524. S note: MDPI stays neutral with regard to jurisdictional claims in published . . .

International Energy Agency (2023) Global energy crisis [online]. International Energy Agency https://www.iea.org/topics/global-energy-crisis. Accessed 18 January 2023

Jamal N (2015) Options for the supply of electricity to rural homes in South Africa. J Energy South Africa 26:58–65

Kale MS, Korenstein D (2018) Overdiagnosis in primary care: framing the problem and finding solutions. BMJ 362:k2820

Kamel Boulos MN, Zhang P (2021) Digital twins: from personalised medicine to precision public health. J Pers Med 11:745

Kenner B, Chari ST, Kelsen D, Klimstra DS, Pandol SJ, Rosenthal M, Rustgi AK, Taylor JA, Yala A, Abul-Husn N (2021) Artificial intelligence and early detection of pancreatic cancer: 2020 summative review. Pancreas 50:251

Khan WA, Khattak AM, Hussain M, Amin MB, Afzal M, Nugent C, Lee S (2014) An adaptive semantic based mediation system for data interoperability among health information systems. J Med Syst 38:1–18

Kheirinejad S, Bozorg-Haddad O, Singh VP, Loáiciga HA (2022) The effect of reducing per capita water and energy uses on renewable water resources in the water, food and energy nexus. Sci Rep 12:1–17

Kortuem G, Kawsar F, Sundramoorthy V, Fitton D (2009) Smart objects as building blocks for the internet of things. IEEE Internet Comput 14:44–51

Krishnamurthi R, Kumar A, Gopinathan D, Nayyar A, Qureshi B (2020) An overview of IoT sensor data processing, fusion, and analysis techniques. Sensors (Basel) 20(21):6076. https://doi.org/10.3390/s20216076. Accessed 26 October 2020, PMID: 33114594; PMCID: PMC7663157.

Kruk ME, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-Dewan S, Adeyi O, Barker P, Daelmans B, Doubova SV (2018) High-quality health systems in the sustainable development goals era: time for a revolution. Lancet Glob Health 6:e1196–e1252

Kumar NM, Chand AA, Malvoni M, Prasad KA, Mamun KA, Islam F, Chopra SS (2020) Distributed energy resources and the application of AI, IoT, and blockchain in smart grids. Energies 13:5739

Lee I, Sokolsky O, Chen S, Hatcliff J, Jee E, Kim B, King A, Mullen-Fortino M, Park S, Roederer A (2011) Challenges and research directions in medical cyber–physical systems. Proc IEEE 100: 75–90

Lee S-I, Celik S, Logsdon BA, Lundberg SM, Martins TJ, Oehler VG, Estey EH, Miller CP, Chien S, Dai J (2018) A machine learning approach to integrate big data for precision medicine in acute myeloid leukemia. Nat Commun 9:1–13

Lindén M, Björkman M (2014) Embedded sensor systems for health-providing the tools in future healthcare. Stud Health Technol Inf 200:161–163

López-Vargas A, Fuentes M, Vivar M (2020) Challenges and opportunities of the internet of things for global development to achieve the United Nations sustainable development goals. IEEE Access 8:37202–37213

Maiurova A, Kurniawan TA, Kustikova M, Bykovskaia E, Othman MHD, Singh D, Goh HH (2022) Promoting digital transformation in waste collection service and waste recycling in Moscow (Russia): applying a circular economy paradigm to mitigate climate change impacts on the environment. J Clean Prod 354:131604

Mavrodieva AV, Shaw R (2020) Disaster and climate change issues in Japan's society 5.0—a discussion. Sustainability 12:1893

Mettler M (2016) Blockchain technology in healthcare: the revolution starts here. In: 2016 IEEE 18th international conference on e-health networking, applications and services (Healthcom). IEEE, New York, pp 1–3

Minsky M (1961) Steps toward artificial intelligence. Proc IRE 49:8–30

Mirskikh I, Mingaleva Z, Kuranov V, Dobrovlyanina O (2021) Problems and negative consequences of the digitalization of medicine. In: The 2018 international conference on digital science. Springer, New York, pp 445–455

Mokhtarian PL, Tang WL (2013) Trivariate Probit models of pre-purchase/purchase shopping channel choice: clothing purchases in northern California. Edward Elgar Publishing, Cheltenham, UK

Mourtzis D (2016) Challenges and future perspectives for the life cycle of manufacturing networks in the mass customisation era. Logist Res 9:1–20

Mourtzis D, Angelopoulos J, Panopoulos N (2022) A literature review of the challenges and opportunities of the transition from industry 4.0 to society 5.0. Energies 15:6276

Myers J, Frieden TR, Bherwani KM, Henning KJ (2008) Ethics in public health research: privacy and public health at risk: public health confidentiality in the digital age. Am J Public Health 98: 793–801

Nam-Chol O, Kim H (2019) Towards the 2 °C goal: achieving sustainable development goal (SDG) 7 in DPR Korea. Resour Conserv Recycl 150:104412

Nandury SV, Begum BA (2015) Smart WSN-based ubiquitous architecture for smart cities. In: 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI). IEEE, New York, pp 2366–2373

Narvaez Rojas C, Alomia Peñafiel GA, Loaiza Buitrago DF, Tavera Romero CA (2021) Society 5.0: a Japanese concept for a superintelligent society. Sustainability 13:6567

Natakusumah K, Maulina E, Muftiadi A, Purnomo M (2022) Digital transformation of health quality services in the healthcare industry during disruption and society 5.0 era. Front Public Health 10

Norris A (2002) Current trends and challenges in health informatics. Health Inform J 8:205–213

Oak M (2007) A review on barriers to implementing health informatics in developing countries. J Health Inform Dev Ctries 1

Oyelade J, Soyemi J, Isewon I, Obembe O (2015) Bioinformatics, healthcare informatics and analytics: an imperative for improved healthcare system. Int J Appl Inf Syst 13:1–6

Pan J, Jain R, Paul S, Vu T, Saifullah A, Sha M (2015) An internet of things framework for smart energy in buildings: designs, prototype, and experiments. IEEE Internet Things J 2:527–537

Pappas IO, Mikalef P, Giannakos MN, Krogstie J, Lekakos G (2018) Big data and business analytics ecosystems: paving the way towards digital transformation and sustainable societies. Springer

Pelc S, Koderman M (2018) Nature, tourism and ethnicity as drivers of (de)marginalization. Nature 3

Poghosyan NM (2020) The development of artificial intelligence and risks for the implementation of genocide and mass killings. J Genocide Res 133:119
Popov V, Kudryavtseva E, Kumar Katiyar N, Shishkin A, Stepanov S, Goel S (2022) Industry 4.0 and digitalisation in healthcare. Materials 15:2140. s Note: MDPI stays neutral with regard to jurisdictional claims in published . . .
Raghupathi V, Raghupathi W (2020) The influence of education on health: an empirical assessment of OECD countries for the period 1995–2015. Arch Public Health 78:1–18
Rahim A (2017) IoT and data analytics for developing countries from research to business transformation. In: International conference on the economics of grids, clouds, systems, and services. Springer, New York, pp 281–284
Rahman R, Qattan A (2021) Vision 2030 and sustainable development: state capacity to revitalize the healthcare system in Saudi Arabia. Inquiry 58:0046958020984682
Ramanathan T, Ramanathan N, Mohanty J, Rehman IH, Graham E, Ramanathan V (2017) Wireless sensors linked to climate financing for globally affordable clean cooking. Nat Clim Chang 7:44–47
Rathore H, Mohamed A, Guizani M (2020) Blockchain applications for healthcare. In: Energy efficiency of medical devices and healthcare applications. Elsevier, New York
Redka MB (2019) Healthcare: use cases today and opportunities for the future
Reisman M (2017) EHRS: the challenge of making electronic data usable and interoperable. Pharm Therap 42:572
Ricciardi W, Pita Barros P, Bourek A, Brouwer W, Kelsey T, Lehtonen L (2019) How to govern the digital transformation of health services. Eur J Pub Health 29:7–12
Ross D (2016) Digital twinning [virtual reality avatars]. Eng Technol 11:44–45
Rüßmann M, Lorenz M, Gerbert P, Waldner M, Justus J, Engel P, Harnisch M (2015) Industry 4.0: the future of productivity and growth in manufacturing industries. Boston Consulting Group 9: 54–89
Saracco R (2019) Digital twins: bridging physical space and cyberspace. Computer 52:58–64
Schinckus C (2022) A nuanced perspective on blockchain technology and healthcare. Technol Soc 71:102082
Serbanati LD, Ricci FL, Mercurio G, Vasilateanu A (2011) Steps towards a digital health ecosystem. J Biomed Inform 44:621–636
Shah S, Jadeja A, Doshi N (2022) An analytical survey of energy efficiency in IoT paradigm. Procedia Comput Sci 210:283–288
Sharma R, Nanda M, Fronterre C, Sewagudde P, Ssentongo AE, Yenney K, Arhin ND, Oh J, Amponsah-Manu F, Ssentongo P (2022) Mapping cancer in Africa: a comprehensive and comparable characterization of 34 cancer types using estimates from GLOBOCAN 2020. Front Public Health 10
Shukla D, Patel SB, Sen AK (2014) A literature review in health informatics using data mining techniques. Int J Softw Hardw Res Eng 2:123–129
Sifat MMH, Choudhury SM, Das SK, Ahamed MH, Muyeen S, Hasan MM, Ali MF, Tasneem Z, Islam MM, Islam MR (2022) Towards electric digital twin grid: technology and framework review. Energy AI 2022:100213
Simonov M, Zich R, Mazzitelli F (2008) Personalized healthcare communication in internet of things. Proc URSI GA08 2008:7
Singh RD, Koshta K, Tiwari R, Khan H, Sharma V, Srivastava V (2021) Developmental exposure to endocrine disrupting chemicals and its impact on cardio-metabolic-renal health. Front Toxicol 3:663372
Sordo M (2002) Introduction to neural networks in healthcare. In: Open clinical: knowledge management for medical care. IGI Global, Hershey, PA
Stevens H, Huys I (2017) Innovative approaches to increase access to medicines in developing countries. Front Med 4:218

Stewart A (2023) Winter is coming: how the energy crisis will change pharma in 2023 [online]. The Medicine Maker. https://themedicinemaker.com/business-regulation/how-the-energy-crisis-will-affect-pharma-in-2023. Accessed 18 January 2023

Tortorella GL, Fogliatto FS, Tlapa Mendoza D, Pepper M, Capurro D (2022) Digital transformation of health services: a value stream-oriented approach. Int J Prod Res:1–15

Tzafestas SG (2018) Ethics and law in the internet of things world. Smart Cities 1:98–120

United Nations (2015) Transforming our world: the 2030 agenda for sustainable development | department of economic and social affairs, Transforming our World: the 2030 Agenda for Sustainable Development. Available at: https://sdgs.un.org/publications/transforming-our-world-2030-agenda-sustainable-development-17981. Accessed 26 January 2023

United Nation ESCAP (2018) ESCAP multi-donor Trust Fund for Tsunami, disaster and climate preparedness: 2016–2017 annual report

Van Tulder R, Rodrigues SB, Mirza H, Sexsmith K (2021) The UN's sustainable development goals: can multinational enterprises lead the decade of action? Springer

Vial A, Stirling D, Field M, Ros M, Ritz C, Carolan M, Holloway L, Miller AA (2018) The role of deep learning and radiomic feature extraction in cancer-specific predictive modelling: a review. Transl Cancer Res 7:803–816

Voigt I, Inojosa H, Dillenseger A, Haase R, Akgün K, Ziemssen T (2021) Digital twins for multiple sclerosis. Front Immunol 12:669811

Wadhwa M (2020) National eHealth authority (NeHA). ICT India Working Paper

Walsh JR, Smith AM, Pouliot Y, Li-Bland D, Loukianov A, Fisher CK (2020) Generating digital twins with multiple sclerosis using probabilistic neural networks. arXiv preprint arXiv:2002.02779

Wang S, Wang J, Wang X, Qiu T, Yuan Y, Ouyang L, Guo Y, Wang F-Y (2018) Blockchain-powered parallel healthcare systems based on the ACP approach. IEEE Trans Comput Soc Syst 5:942–950

Weng J, Mcclelland J, Pentland A, Sporns O, Stockman I, Sur M, Thelen E (2001) Autonomous mental development by robots and animals. Science 291:599–600

World Health Organization (2016) Innov8 approach for reviewing national health programmes to leave no one behind: technical handbook

World Health Organization (2022) Health topics: health and energy [online]. World Health Organization. https://www.who.int/health-topics/energy-and-health#tab=tab_1. Accessed 17 January 2023

Xafis V (2015) The acceptability of conducting data linkage research without obtaining consent: lay people's views and justifications. BMC Med Ethics 16:1–16

Xu X, Lu Y, Vogel-Heuser B, Wang L (2021) Industry 4.0 and industry 5.0—inception, conception and perception. J Manuf Syst 61:530–535

Yaqoob I, Salah K, Jayaraman R, Al-Hammadi Y (2022) Blockchain for healthcare data management: opportunities, challenges, and future recommendations. Neural Comput Appl 34:11475–11490

Yu K-H, Beam AL, Kohane IS (2018) Artificial intelligence in healthcare. Nat Biomed Eng 2:719–731

Záklasník M, Putnová A (2019) Digital society–opportunity or threat? Case studies of Japan and The Czech Republic. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis 67:1085–1095

Zanella A, Bui N, Castellani A, Vangelista L, Zorzi M (2014) Internet of things for smart cities. IEEE Internet Things J 1:22–32

Zengin Y, Naktiyok S, KaygıN E, Kavak O, Topçuoğlu E (2021) An investigation upon industry 4.0 and society 5.0 within the context of sustainable development goals. Sustainability 13:2682

Zhao H, Zhang Y, Peng Y, Xu R (2017) Lightweight backup and efficient recovery scheme for health blockchain keys. In: 2017 IEEE 13th international symposium on autonomous decentralized system (ISADS). IEEE, New York, pp 229–234