This article has been accepted for publication in a future proceedings of this conference, but has not been fully edited. Content may change prior to final publication.
Citation information: DOI: 10.1109/gDigiHealth.KEE62309.2024.10761673, 2024 Global Digital Health Knowledge Exchange & Empowerment Conference (gDigiHealth.KEE)

Shaping the Future of Healthcare: The Key Characteristics and Drivers of Smart Hospitals

Alanoud Almarri*, Ziad Hunaiti†, Mohammad Sh. Daoud‡, Nadarajah Manivannan§
* *Directorship of the Nursing/Midwifery Corporate Workforce Hamad Medical Corporation*, Qatar
Email: aalmarri6@hamad.qa
†*Department of Electronic and Electrical Engineering, Brunel University London,* Uxbridge, UK
Email: ziad.hunaiti@brunel.ac.uk
‡*College of Engineering, Al Ain University,* Abu Dhabi,, UAE
Email: mohammad.daoud@aau.ac.ae
§ *Brunel Design School, Brunel University London*, Uxbridge, UK
Email: nadarajah.manivannan@brunel.ac.uk

***Abstract*—this paper aims to explore and identify the key characteristics that define smart hospitals, as well as the primary drivers fostering the transformation of conventional hospitals into smart healthcare environments. As the healthcare sector continues to embrace technological innovation, smart hospitals are emerging as a critical model for improving patient care, efficiency, and accessibility. This paper anticipated to offer valuable insights for researchers and stakeholders in healthcare, guiding them in establishing the necessary framework or roadmap for the successful digital transformation of hospitals into smart, technology-driven systems..**

Keywords—Smart Hospitals, Artificial Intelligence, Data Security, Personalized Care.

I. INTRODUCTION

The concept of smart hospital evolves from the concept of traditional hospital and healthcare. It fully integrated with technology while improving on patient care with its services growing to not exclude anyone. The reach of a smart hospital extends to any location where patients or healthy individuals may be, such as their homes, workplaces, recreational areas, and other points of care. Personalised, context-sensitive support is provided by these environments by integrating sensors and advanced interaction technologies that can connect two people such as healthcare professionals and patients no matter their location or distance or even time difference. The heightened advancements in technology has meant ease of interconnectedness between two locations that are far from one another which means healthcare professionals can have contact with their patients no matter where they go or even if they are in a different time zone completely. This creates a continued ease of patient care as well monitoring which benefits the patients more in their quality of life and everyday life [1]. Help with daily tasks, monitoring of health, improving patient safety, and facilitating access to social, medical, and emergency services are included. Smart healthcare can provide medical, social, and economic benefits to various individuals by offering a variety of services. In addition to providing emergency assistance, they can enhance comfort and support autonomy [1].

Utilising this concept, healthcare professionals, staff, etc take into account the different needs of using the smart hospital. For example, sharing patient information with experts in a specific field who are across the world to get professional advice on patient care, or using it for 24/7 monitoring of a patient. Patients are not the only ones who benefit from using a smart hospital. Other recipients could be researchers in the pharmaceutical or medicine or disease field. Another example researchers can use data saved for different patients with specific diseases that were treated in hospitals over the globe to see if a pattern exists or not [2].

This expansive, interconnected approach demands robust data security and privacy measures, high-quality service standards, seamless data and service interoperability, and advanced network and communication infrastructures [1], [3],[4] .The modern smart hospital strives to improve patient experiences, reduce the workload on healthcare professionals, and lower costs and accident rates, ultimately creating a more efficient and responsive healthcare system [5]. There are multiple uses and characterisation of this concept that are beneficial to improving healthcare and patient care in general.
This paper aims to identify the key characteristics of smart hospitals and the drivers for transforming conventional hospitals into smart hospitals, offering guidance to researchers and stakeholders in establishing the necessary framework or roadmap for the digital transformation of healthcare.

II. METHODOLOGY

This paper employs a qualitative, literature-based review to explore and identify the key characteristics and drivers of smart hospitals. The methodology involves a review of academic journals, industry reports, case studies, and relevant publications. This was conducted to identify both the characteristics and drivers of smart hospitals, as shown in Figure 1. The selection criteria for the sources included their relevance to the digital transformation of healthcare, the implementation of smart hospital technologies, and recent advancements in healthcare innovation.

This article has been accepted for publication in a future proceedings of this conference, but has not been fully edited. Content may change prior to final publication.
Citation information: DOI: 10.1109/gDigiHealth.KEE62309.2024.10761673, 2024 Global Digital Health Knowledge Exchange & Empowerment Conference (gDigiHealth.KEE)

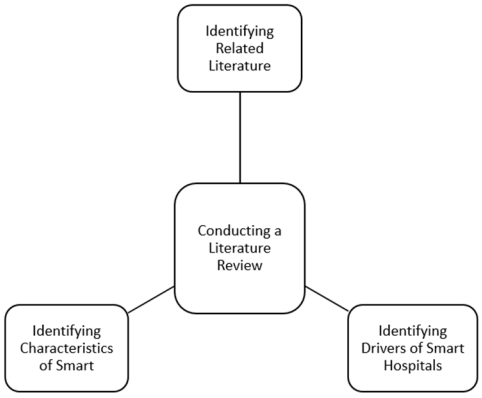

Fig 1 Research Protocol

III. Characteristics of Smart Hospitals

One characterisation of smart hospitals is the integration of advanced technologies like artificial intelligence (AI), surgical robots, and mixed reality. This is transforming disease diagnosis and treatment, making processes more efficient and accurate. AI has significantly improved clinical decision support systems (CDSS), achieving high accuracy in diagnosing conditions such as hepatitis, lung cancer, and skin cancer (Tian et al. 2019). In fields like pathology and imaging, AI often surpasses human doctors by detecting patterns in vast datasets. A notable CDSS example is IBM's Watson, which analyses extensive clinical data to provide optimal diagnostic solutions, especially effective in managing diabetes and cancer [2]. AI also enhances treatment precision, exemplified by smart radiomics in tumour radiotherapy and the use of surgical robots [2].

A second characterisation is the utilisation of mobile health services which use mobile devices such as cell phones, tablets, and wearables to provide healthcare. Personal health records are a key component of this system, enabling individuals to self-monitor and manage their health by gathering information from various medical institutions, as well as tracking data like activity levels, weight, and blood glucose via smartphones

Stanford University study reported that 81% of participants using smartwatches or fitness trackers displayed heart rate variability changes up to 9 days before COVID-19 symptoms appeared [5]. With the increasing need for mobile access to medical services, mobile electronic medical records are becoming more essential. An NHS app in the UK allows access to hospital mobile electronic medical records, prescription refills, appointments, and treatment reviews [6].

A third characterisation is telehealth. With the help of information and communication technology, telehealth is a method of providing medical services remotely. There are various applications of this approach, such as tele intensive care units, teleconsultations, and tv collaborations. Virtual agents like chatbots and wearable devices can be used synchronously or asynchronously without requiring physical contact [7]. An example of this characterisation can be seen In the United States, an online service provides healthcare services and consultants for people who may live in remote locations and cannot easily access a healthcare service. This characterization allows patients to simply use an electronic device such as a phone or tablet to speak to a healthcare professional such as a health coach who can guide them through treatment plans, consultations, advice, etc. Another use of this characterisation of a smart hospital is being able to provide a direct link between healthcare professionals or staff and patients who are in intensive care units [8]via radio services or visual devices to exchange constant communications [9]. In [9]found that the tele-ICU program at Johns Hopkins Hospital reduced ICU stay duration and improved clinical outcomes, resulting in a 24.6% reduction in cost per case.

Prevention and observation make up a fourth characteristic. In the conventional approach to illness prediction and risk assessment, individuals collect patient data in the field directly from hospital physicians, comparing information and data before drawing conclusions. This may result in a delay in the public's access to information about self-defence. Moreover, because hospitals are not adjacent to one another, it might take significantly longer when data collection is done face-to-face between hospitals. Patients' data will be kept in an online format in smart hospitals, making it easily accessible from anywhere without requiring actual hospital visits. This will also speed up the viewing of the data [2]. Wearable technology, which can upload data to applications, a storage field, the cloud, etc., can be used for this. It continuously gathers information that physicians may access [2].

Helping with medication research is a fifth characteristic. The process of developing a new drug begins with screening, discovery, and clinical trials, all of which are overseen by manual procedures [2]. This has occasionally resulted in mistakes that have the potential to be lethal, such as when a medicine is developed and has serious adverse effects or even outcomes that are intentionally altered by those participating in the process. A smart hospital can capture every piece of process data without anybody changing it, as well as any discoveries the researchers have made. Additionally, it may be utilised to quickly do computations or double-check calculations performed by the researchers [2].

Hence, the concept of smart hospitals signifies a transformative shift in healthcare, integrating advanced technologies to enhance patient care and streamline operations. By leveraging a variety of technology such as artificial intelligence, mobile health services, and telehealth, these facilities are able to produce real-time communication and monitoring, ensuring that healthcare professionals can provide timely support, regardless of geographical barriers or disabilities or any external or internal factors that can hinder a patient. This interconnected approach not only improves patient outcomes through personalised care but also empowers researchers by offering access to vast datasets for analysis and pattern recognition. As smart hospitals continue to

This article has been accepted for publication in a future proceedings of this conference, but has not been fully edited. Content may change prior to final publication.
Citation information: DOI: 10.1109/gDigiHealth.KEE62309.2024.10761673, 2024 Global Digital Health Knowledge Exchange & Empowerment Conference (gDigiHealth.KEE)

evolve, they promise to improve medication research and disease prevention, making healthcare more efficient and accessible.

Ultimately, the smart hospital concept prioritises patient safety and comfort while reducing the burden on healthcare providers, ensuring a more responsive and efficient healthcare system. By addressing the diverse needs of patients and healthcare professionals alike, smart hospitals represent a future where quality care is available anytime and anywhere, leading to better health outcomes and improved quality of life for individuals around the globe. The key characteristics of smart hospitals is summarized in Table 1.

TABLE I. KEY CHARACTERISTICS OF SMART HOSPITALS

Characteristic	Description
Integration of Advanced Technologies	Utilize Artificial Intelligence (AI), surgical robots, and mixed reality to enhance diagnosis, treatment, and efficiency in healthcare processes.
Mobile Health Services	Use mobile devices such as smartphones and wearables for patient self-monitoring and remote health management, including access to personal health records.
Telehealth	Remote delivery of healthcare services via teleconsultations, tele-ICUs, and virtual agents, ensuring continuous patient care anytime, anywhere.
Prevention and Monitoring	Implementation of data collection and monitoring through wearable technology, enabling early illness detection and easy access to patient information for healthcare providers.
Support for Healthcare Research	Foster the use of digital tools in healthcare research to streamline drug discovery, clinical trials, and data collection, improving accuracy, safety, and patient care.

IV. CHARACTERISTICS OF SMART HOSPITALS

Smart hospitals have become increasingly popular over the years with its efficiency and ease of usage as well as improved patient care. They are expected to keep gaining traction as society and the globe further develops alongside technology and medicine. As illustrated in figure 2. There are several key drivers that are contributing to their increasing popularity: technological advancements, digital citizens societies, change in patient care, healthcare workforce shortage, cost of healthcare delivery, recent pandemic COVID 19 that the whole world experienced.

Fig 2 Key Drivers' Smart hospital

A significant role is played by technological advancements, including Internet of Things devices, Artificial Intelligence (AI), and advanced data analytics. As digital citizens, especially Generation Z, become more prevalent, the demand for more technologically integrated healthcare environments has increased. In addition to the rise in healthcare costs, institutions are also seeking cost-effective solutions that don't compromise quality due to the rising costs of healthcare services. In addition to improving service delivery, smart hospitals promise to reduce operational costs. Healthcare workers shortages further exacerbate the need for more efficient systems that can optimise existing resources and support staff.

Finally recent events have emphasised why hospitals need some change. The COVID-19 pandemic has emphasised the need for a flexible and resilient healthcare infrastructure, accelerating the adoption of smart hospital technologies in order to manage surges in demand and enhance overall resilience due to how much strain the healthcare system of not just one country but many countries around the world were due to this pandemic. This recent event highlighted the limitations of traditional hospitals and how crucial technology can be in patient care. It also showed just how important it is to improve and advance the healthcare system to be able to manage anything that occurs whether it be a local epidemic or a pandemic.

Overall, these factors are reshaping the landscape of healthcare, steering it towards more enhancement of patient care and improving quality of life for the patients. It shows reasons why a smart hospital may be needed or why some countries may consider it as a viable option due to how it can counter limitations and provide advantages. Here's a more comprehensive look at the different drivers to why smart hospitals are needed.

A. Technological advancement

As the world on a global scale advances forward with developments, hospitals share that same fate as well. Doctors form all time periods have wanted to make sure they provide the best care possible using the resources they had at the time such as Dr. Laennec in France in the early 19h century creating a hollow wooden tube which was the first stethoscope to listen to patient heartbeats [10]. Using what resources the time period had, the healthcare industry did what they could. And in a modern contemporary world, digitization of healthcare occurred moving forward with technological advancements [11]. The increased use of digital technologies such as monitoring systems, online tools, Artificial Intelligence (AI) has been incorporated within the healthcare service.

For example using technology to monitor a patient who is not near the doctor or using artificial intelligence to test every possible scenario for creation of medication or using online tools to do remote consultation without the need to be face to face. Other examples are using smartphone-based photo plethysmography as a diagnostic tool. This uses a smartphone camera, a deep neural network, and AI technology, incorporated into the video to see if it can detect diabetes in a patient [12]. AI has many uses such as

This article has been accepted for publication in a future proceedings of this conference, but has not been fully edited. Content may change prior to final publication.
Citation information: DOI: 10.1109/gDigiHealth.KEE62309.2024.10761673, 2024 Global Digital Health Knowledge Exchange & Empowerment Conference (gDigiHealth.KEE)

it being used and utilised in its radiology or pathology department. Diagnostic images (such as x-rays, magnetic imaging, and pathology slides) can be improved to support more accurate and timely diagnoses and personalised treatment plans for cancer and renal disease [13]. Another usage of artificial intelligence can be seen by drug researchers. It can be used for patient recruitment, virtual engagement, and literature reviews, as well as to detect and refine pharmaceutical targets and create numerous scenarios to see how they will end such as increasing a drug dosage and whether it will lead to death of patient or their recovery [14].

B. *Digital citizens societies*

With each time period and advances in technology, a new generation is born. Whether it be the boomers, millienus to the recent generation z, each generation is affected by the advancements and trends of the time period they are in. Generation Z are currency born and live in a generation where technology has evolved and become a daily part of life which contrasts to say the boomer generation. These advancements in technology have caused the new generation of individuals to be born in an environment where they are exposed to constant technological changes as well as the usage of said technology being normal for them [15]. This requires the generation to understand said technology which has made them faster to adapt to technology than previous generations and makes them more accepting of advancements [15]. Generation z is different to the other generations before them as this is the only generation so far that have always had access to the internet. It's the only generation that never experienced what society or life was like before the internet was established. They have also been called digital natives due to this as the children of generation z have always had access to internet or technological advancements [16].

Now with this generation comes the need to integrate more technology in a service. Hospitals are not immune to this as this generation and the generations that come after them will be the patients who use the healthcare service. Accepting technological uses is crucial as these patients will demand it due to it being a normal part of their life and them not seeing why someone wouldn't want to use it, especially if it can aid and enhance one's life or job. The other factor is that the next generation of doctors, nurses or any type of healthcare professional will also come from a generation that has only ever experienced a society that has technological ecosystems. The future professionals will view technology as a normal part of life and will expect their place of work to have this function. Thus, a smart hospital changes due to the new types of people being born in a generation where society has adapted technological uses. This new generation and future generations will see technology as normal and everyday life, which contrasts to older generations who experienced the world when technology was not so easily accessed or even existed.

C. *Change in patients care*

Technology is not the only subject that has advanced in years. Medicine and science advances forward improving patient care and outcomes.

It has advanced so much that an ageing population is a common sight around the world. Medication and treatments are able to prolong life expectancy. Global life expectancy is expected to increase from 46–89 years to 66–93 years throughout the 21st century according to the UN Department of Economic and Social Affairs Population Division (2004). Globally, from 2100 to 2300, the proportion of people aged 65 and older will rise from 24% to 32% (UN Department of Economic and Social Affairs Population Division, 2004). This will result in changes in patient care. However, with an increased ageing population, the demand is then to ensure the quality of life the elderly get and taking into consideration the challenges they may face. This is a factor hospitals have to take into consideration. For example, an elderly person may not be physically able to go to a face to face appointment which is where remote appointments are the favourable outcome ensuring the elderly person still gets the same service despite not being physically in the hospital or general practice. This change in patient care can also lead to home care that is supported by healthcare professionals using the smart hospital to monitor. Data is collected and analysed remotely from these homes using sensors, actuators, and biomedical monitors [17]. Data is monitored, diagnoses are provided, and assistance is initiated as required.

As a result of advances in technology, wearables and implantable devices can now be used to monitor people inside and outside of their homes round-the-clock [17]. For example there's swallowable microsystems that can be used should the elderly person have any motor function issues or any wearable items feel too heavy for them. All devices where there is something wearable, a camera setup in the home or something to swallow can be done at home or worn when going out to do everyday life routines. They are connected through wired or wireless or Bluetooth networks that are connected to a system that healthcare professionals can access to check up on their patient when they need to. Each of these devices are equipped with diagnostic capabilities as well as monitoring services ensuring the one wearing or using the device gets the same treatment or monitoring as they would in a hospital setting. They can monitor vital signs, blood oxygenation, heart rate, blood levels, etc. These devices can be used for a variety of conditions such as chronic conditions (e.g. diabetes). For example Japan uses them [17]. This can be seen via utilising this type of technology to monitor elderly while they live independently without feeling caged. IR sensors in bedrooms, magnetic switches on doors, and fully automated biomedical devices in bathrooms are used to monitor residents' activities and vital signs in 13 Welfare Techno-Houses (WTH) established by the Japanese Ministry of International Trade and Industry [18]. Alternatively, seen in Osaka, where a system has been built with smart house design in mind that has around 167 sensors designed to detect unusual events resulting from illness or accidents [19]. This is via the different sensors

This article has been accepted for publication in a future proceedings of this conference, but has not been fully edited. Content may change prior to final publication.
Citation information: DOI: 10.1109/gDigiHealth.KEE62309.2024.10761673, 2024 Global Digital Health Knowledge Exchange & Empowerment Conference (gDigiHealth.KEE)

applied in the house such as the 17 different electrical appliances (such as rice cookers, air conditioners, refrigerators, and TVs) have sensors associated with specific activities like working, eating, washing, or cooking [19].

D. Healthcare workforce shortage

As with every industry and service, healthcare services also experience a shortage of healthcare professionals and workers. Due to increasing patient demand and a shortage of new entrants, the healthcare sector is facing a significant shortage of professionals. The shortage of healthcare workers is a pressing issue that affects the quality of care and the efficiency of the healthcare industry. This problem is not unique to any one region but is a global concern affecting both developed and developing countries.

Integrating cutting-edge technology like artificial intelligence (AI) into healthcare settings is one way to overcome this shortfall. Existing staff members can benefit from technology by having their jobs marginally made simpler. For example, patients can be continuously monitored without requiring a nurse, physician, or surgeon to be on hand 24 hours a day. By improving the skills of current employees and optimising processes, artificial intelligence (AI) and other technology advancements might help lessen the effects of a labour shortage. AI-powered systems, for example, have the ability to continually monitor patients, which eliminates the need for nurses, doctors, and surgeons to constantly oversee patients manually [20]. This lessens the workload for medical personnel and frees them up to concentrate on more difficult jobs that call for direct patient contact, such interacting with patients and providing treatment. In addition, due to the ease of capturing information and data, there is an increasing amount of data. With shortage of workers, digital technologies can easily manage this information so current workers don't have to waste time sifting through numerous pieces of data. Technology equipped into the hospital turning it into a smart hospital can assist where there are limits due to shortage of staff such as interprets painting data.

E. Cost of healthcare delivery

With budgets and trying to make sure money is spent wisely, the healthcare industry faces many costs, which are increasing at every turn. iIt is projected that by 2050 healthcare costs would drastically increase and it is expected to account for 20 to 30% of a country's GDP as a whole which has been classed as unstable and unsustainable [21]. Because of investments into healthcare, shareholders, governments are looking at ways to enhance care while reducing service costs and one method is smart hospitals [21].

Having investments made into a hospital such as turning it into a smart hospital has many advantages such as effective 24/7 monitoring of a patient to quickly calculations being done in clinical trials via the use of artificial intelligence. These investments are crucial to better benefit the public. There is a demand for healthcare professionals to provide the best possible care with the best possible tools and to learn new ways to provide this service. This could involve having the tools needed for treatment at home such as remote consultations where doctor is at hospital and patient at home or wearable devices that can monitor the patient while they going about their daily lives and doctor checking on their vitals, blood sugar heart rate from the hospital.

Incorporating technology and making a hospital a smart hospital can also reduce costs. For example, a hospital with pooled IT resources such as multiple cloud storage networks [22] . One not only is this easy to access for the healthcare professional at any time they want but it reduces any accidental errors made in reports that are being written [22]. Secondly, it reduces the extra cost needed to maintain the records or the operational costs to manage this. Using the technology cloud system is less time consuming for the healthcare professional who is being paid to cater to patients' care and quality of care [22].

F. Covid 19

COVID 19 became a worldwide pandemic where everyone was affected by it. It first began in 2019 in Wuhan China where it then spread all around China before spreading to different parts of the world. By March 2020, it had become a pandemic.

Smart hospitals became even more vital during this worldwide pandemic when lockdown protocols and policies were put in place where people were limited to go outside and to stay at home unless absolutely necessary to leave the safety of their home. This leads to remote consultations, a process that only requires an electronic device (such as phones, laptop, tablets) and wifi or call services [23]. It played a crucial role in supporting COVID-19 patients who couldn't leave their homes due to them being contagious. It helped alleviate the strain on inpatient care, and ensured continued access to routine services. While they cannot entirely replace face-to-face consultations, remote consultations offer a cost-effective and efficient means of accessing care no matter the time or place aiding patients who may not be able to leave their home to go to hospitals or GP [23]. A remote consultation, whether between healthcare professions or between doctors and patients, can be done with numerous pieces of technology. This method of healthcare existed before the pandemic with healthcare slowly utilising advances in technology [23].

Prior to the global pandemic, remote consultations were met with skepticism as to how a healthcare professional can aid a patient if they cannot see or treat in person. Due to this remote consultations were not often used [23].In addition, using online technology was a slow development in the healthcare industry where phone calls or emails were more used to remind patients they have face to face appointments or have their medication sent to pharmacies. In addition if a remote consultation did occur due to a patient not able to come in, often phone calls would be used instead of video calls such as face time or using video meeting apps such as zoom or google meet [24]. Healthcare professionals didn't see the benefit of these video meeting apps such as it giving the healthcare professional a visual of how the patient looked which could tell them how the

patient is doing or not such as skin or eyes [24]. When the pandemic hit and then it no longer existed, remote consultations became more common and used as the public and healthcare professionals experienced its full benefits.

This method of patient care began to increase in many countries such as the United Kingdom and Croatia [24]. Guidelines and laws were also created to ensure the safe usage of online prescribing medication and remote consultations in a variety of countries such as Malta [24]. Healthcare professionals have also undergone training - which were created for this purpose after seeing the benefits of it -to use remote consultations such as in Sweden [24]. General practitioners (GP) are a healthcare service that uses remote consultations even more. For example in England, there was a sharp increase in telephone consultations in comparison to face to face appointments. This can be seen between March 2 and May 18, 2020 where the number of telephone consultations in England weekly took a rapid increase from 856,631 to 2,022,798 [24]. France is another location that has seen this sharp increase. In 2018, remote or phone occupations became an official public service in France however it only became increasingly popular during the pandemic and kept being popular after the lockdown was no longer declared. This can be seen between March and April 2020 where 5.5 million teleconsultations were conducted in March only to increase to 56,000 in April [24]. After lockdown the remote consultations did slow down but were still higher than in the pre-pandemic world.

V. Conclusion & Future Work

The concept of a smart hospital represents an evolution from traditional healthcare facilities by integrating advanced technologies to enhance patient care. Unlike conventional hospitals, smart hospitals expand services beyond physical locations, enabling healthcare delivery anytime and anywhere, such as homes, workplaces, or recreational areas. Achieving the benefits of smart hospitals relies on a robust technological infrastructure, including elements like sensors, artificial intelligence, mobile healthcare, and telemedicine to facilitate seamless communication between healthcare professionals and patients, regardless of geographic or time barriers. Key features include 24/7 patient monitoring, data sharing with global experts, and integration with mobile health services. The smart hospital model also supports researchers in accessing global patient data for improved diagnostics and treatment development. Additionally, it enhances patient safety, autonomy, and quality of life by providing personalized, real-time care. In response to challenges like workforce shortages, rising healthcare costs, and global health crises like COVID-19, smart hospitals offer innovative solutions that increase efficiency, reduce operational costs, and ensure continuous care. The smart hospital concept represents a major shift toward a future where healthcare is more accessible, efficient, and patient-centered, empowering both patients and healthcare professionals with cutting-edge tools and technologies. However, such benefits will not be achieved without the right healthcare digital transformation strategy.

References

[1] A. Holzinger, C. Röcker, and M. Ziefle, "From Smart Health to Smart Hospitals," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 8700, pp. 1–20, 2015, doi: 10.1007/978-3-319-16226-3_1.

[2] S. Tian, W. Yang, J. M. Le Grange, P. Wang, W. Huang, and Z. Ye, "Smart healthcare: making medical care more intelligent," *Global Health Journal*, vol. 3, no. 3, pp. 62–65, Sep. 2019, doi: 10.1016/J.GLOHJ.2019.07.001.

[3] M. S. Daoud, A. Ayesh, M. Al-Fayoumi, and A. A. Hopgood, "Location prediction based on a sector snapshot for location-based services," *Journal of Network and Systems Management*, vol. 22, no. 1, pp. 23–49, Jan. 2014, doi: 10.1007/S10922-012-9258-9/METRICS.

[4] H. Al-Mimi, N. A. Hamad, M. M. Abualhaj, M. Sh. Daoud, A. Al-Dahoud, and M. Rasmi, "A n Enhanced Intrusion Detection System for Protecting HTTP Services from Attacks," *International Journal of Advances in Soft Computing and its Applications*, vol. 15, no. 2, pp. 67–84, 2023, doi: 10.15849/IJASCA.230720.05.

[5] E. Kaldoudi, "Smart hospital: The future of healthcare," *Comput Struct Biotechnol J*, vol. 24, pp. 87–88, Dec. 2024, doi: 10.1016/J.CSBJ.2023.12.011.

[6] NHS, "https://www.nhs.uk/nhs-app/about-the-nhs-app/. ," 2021. Accessed: Sep. 11, 2024. [Online]. Available: https://digital.nhs.uk/data-and-information/publications/statistical/mi-appointments-in-general-practice/current

[7] J. Wosik *et al.*, "Telehealth transformation: COVID-19 and the rise of virtual care," *Journal of the American Medical Informatics Association*, vol. 27, no. 6, pp. 957–962, Jun. 2020, doi: 10.1093/JAMIA/OCAA067.

[8] S. Kumar, S. Merchant, and R. Reynolds, "Tele-ICU: Efficacy and Cost-Effectiveness Approach of Remotely Managing the Critical Care," *AACE Clin Case Rep*, vol. 7, no. 1, p. 1, Aug. 2021, doi: 10.2174/1874431101307010024.

[9] B. A. D. T. B. M. P. P. J. M. Z. N. A. G. R. H. Rosenfeld, "Intensive care unit telemedicine: Alternate paradigm for providing continuous intensivist care," *Crit Care Med*, vol. 28, no. 12, pp. 3925–3931, Dec. 2000.

[10] T. O. Cheng, "How Laënnec invented the stethoscope," *Int J Cardiol*, vol. 118, no. 3, pp. 281–285, Jun. 2007, doi: 10.1016/J.IJCARD.2006.06.067.

[11] B. Meskó, Z. Drobni, É. Bényei, B. Gergely, and Z. Győrffy, "Digital health is a cultural transformation of traditional healthcare," *Mhealth*,

vol. 3, pp. 38–38, Sep. 2017, doi: 10.21037/MHEALTH.2017.08.07.

[12] M. Jabara *et al.*, "Artificial Intelligence-Based Digital Biomarkers for Type 2 Diabetes: A Review," *Canadian Journal of Cardiology*, Aug. 2024, doi: 10.1016/J.CJCA.2024.07.028.

[13] L. Barisoni, K. J. Lafata, S. M. Hewitt, A. Madabhushi, and U. G. J. Balis, "Digital pathology and computational image analysis in nephropathology," *Nature Reviews Nephrology 2020 16:11*, vol. 16, no. 11, pp. 669–685, Aug. 2020, doi: 10.1038/s41581-020-0321-6.

[14] M. J. Lamberti *et al.*, "A Study on the Application and Use of Artificial Intelligence to Support Drug Development," *Clin Ther*, vol. 41, no. 8, pp. 1414–1426, Aug. 2019, doi: 10.1016/J.CLINTHERA.2019.05.018.

[15] J. Lu, Q. Hao, and M. Jing, "Consuming, sharing, and creating content," *Comput Human Behav*, vol. 64, pp. 55–64, Nov. 2016, doi: 10.1016/J.CHB.2016.06.019.

[16] S. K. Wang, H. Y. Hsu, T. Campbell, D. C. Coster, and M. Longhurst, "An investigation of middle school science teachers and students use of technology inside and outside of classrooms: considering whether digital natives are more technology savvy than their teachers," *Educational Technology Research and Development*, vol. 62, no. 6, pp. 637–662, Dec. 2014, doi: 10.1007/S11423-014-9355-4/METRICS.

[17] M. Chan, E. Campo, D. Estève, and J. Y. Fourniols, "Smart homes - Current features and future perspectives," *Maturitas*, vol. 64, no. 2, pp. 90–97, Oct. 2009, doi: 10.1016/J.MATURITAS.2009.07.014.

[18] T. Tamura, T. Togawa, M. Ogawa, and M. Yoda, "Fully automated health monitoring system in the home," *Med Eng Phys*, vol. 20, no. 8, pp. 573–579, Oct. 1998, doi: 10.1016/S1350-4533(98)00064-2.

[19] Matsuoka K, "Aware home understanding life activities," in *In Zhang D, and Mokhtari M, (Eds.), Towards a human-friendly assistive environment*, Amsterdam, the Netherlands: IOS Press, 2004, pp. 186–193.

[20] S. Patil and H. Shankar, "International Journal of Multidisciplinary Sciences and Arts Transforming Healthcare: Harnessing the Power of AI in the Modern Era," vol. 2, no. 1, 2023, doi: 10.47709/ijmdsa.vxix.xxxx.

[21] S. Sakr and A. Elgammal, "Towards a Comprehensive Data Analytics Framework for Smart Healthcare Services," *Big Data Research*, vol. 4, pp. 44–58, Jun. 2016, doi: 10.1016/J.BDR.2016.05.002.

[22] L. Giorgio, D. Mascia, and A. Cicchetti, "Hospital reorganization and its effects on physicians' network churn: The role of past ties," *Soc Sci Med*, vol. 286, p. 113885, Oct. 2021, doi: 10.1016/J.SOCSCIMED.2021.113885.

[23] G. A. W. N. F. Aissat, "Keeping what works: remote consultations during the COVID-19 pandemic," *Eurohealth (Lond)*, vol. 26, no. 2, pp. 73–76, 2020.

[24] E. Donaghy *et al.*, "Acceptability, benefits, and challenges of video consulting: a qualitative study in primary care," *Br J Gen Pract*, vol. 69, no. 686, pp. E586–E594, 2019, doi: 10.3399/BJGP19X704141.