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Research Article

Encoding IoT for patient monitoring and smart healthcare: connected healthcare system fostering health 6.0

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ABSTRACT

The Internet of Things (IoT) has transformed healthcare delivery and patient monitoring. This evolution has led to an emerging paradigm termed Health 6.0, in which connected IoT devices form the backbone of care delivery. IoT-enabled systems provide round-the-clock monitoring that supports early detection of disease and more precise treatment decisions, improving the efficiency and effectiveness of care. For example, IoT devices like wearables or medical equipment will be able to send health data in real time back to healthcare providers so they can leverage the additional information for better diagnosis, treatment as well as care management. This ecosystem provides the infrastructure for exchanging data between different healthcare systems so physicians can quickly access all of the information they need at point-of-care. IoT can also be used in patient monitoring, so that healthcare providers have data-supported decisions on care processes and treatment strategies; by predicting the health problems before reaching critical levels. This paper reviews the concept of the Smart Hospital and examines its potential to reshape healthcare in the Health 6.0 era, together with the associated technical, legal and governance challenges.

1. INTRODUCTION

Smart healthcare systems based on IoT enable patients to be proactive in maintaining their health. Patients can track their health metrics, receive real-time feedback and attend telemedicine consultations [1-3] through mobile applications and smart devices, which improves the overall care experience. However, several challenges remain, including data security [4], since data can be intercepted and modified between the sender and receiver in an IoT network; privacy, since standards bodies have yet to fully define how patient-specific information should be collected and stored; and regulatory issues [5]. Addressing these issues is necessary to realise the full potential of IoT innovation [6] in healthcare delivery. It is expected that IoT will enable healthcare providers to provide better, more personalized and proactive care than ever before, improving patient outcomes and supporting a new era in healthcare provision. As a result, the healthcare markets are receiving a multitude of new healthcare applications. Additionally, 'tailored preventative health coaches' (virtual health advisers) will develop to assist consumers in managing chronic and diet-related disorders using such apps. There are many consumer wearable devices and health apps available globally, with two main service sector categories: management of health conditions and wellness. Wellness-management applications frequently make it easier to track and alter lifestyle, stress, and diet choices including weight reduction[7], food diaries, stress management, quitting smoking, and moderate alcohol consumption. Apps for managing health conditions [8-11] provide information on illnesses and ailments, facilitate medical access, and facilitate

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treatment regimens like diabetes self-management, atrial fibrillation management, or treatment for mental disorders. ICT is now widely used both within and outside hospitals, and its capabilities have improved considerably. The present healthcare system is focused on employing cell phones or wearable technology[12] to manage a specific ailment. Individual data sets only accurately reflect particular facets of an individual's condition; for example, glucose meters only accurately indicate a small portion of a person's overall health[13-15]. In addition, wearable devices like smart watches demand user initiative, which frequently results in a loss of interest over time, while retention rates for mobile apps tend to decline after the initial phase[16].

The application of machine learning approaches to track human activity[17-19] is a foundational asset that is changing the way individuals and clinicians understand and manage personal wellness through Smart Healthcare Informatics [20]. Using cutting-edge machine learning models, it allows for a continuous and detailed real-time observation of everyday activities[21-24] which in turn can be used to predict when clinical intervention is needed, thus enabling more personalised and proactive care. Data is gathered through a host of wearable sensors and smart devices in real-time, tracking different aspects of how an individual moves about, behaves under specific pressures or during certain activity periods[25]. This data is then run through advanced machine learning algorithms to detect complex patterns, outliers and trends that may be indicative of changes in health. By comparing this with other established medical information, we can identify activity patterns of likely injury or illness that correlate most closely with these abnormalities.

1.1 Significance and Relevance of the Study

Smart Healthcare is significant because it can improve the quality, accessibility and efficiency of healthcare delivery [26]. Improving patient workflows and communication with providers via digital platforms, stream-lining administrative processes, optimising resource allocations build a more flexible responsive health care system[27]. Telemedicine allows clinicians to consult patients remotely, overcoming geographical barriers and widening access to healthcare services. The primary concern is around data security and privacy, as well as interoperability across the many disparate healthcare systems and devices[28-30]. In addition, healthcare professionals must be sufficiently trained to effectively use this technology and put the insights into meaningful context. Smart Healthcare is a disruptive technology and regulatory frameworks must be sensitive to the ethical, legal as well technical implications. It combines advanced technology with current medical knowledge to improve patient outcomes and healthcare operations, ultimately leading to a more adaptive and personalized healthcare ecosystem[31-34]. Applications in Smart Healthcare are reforming the healthcare spectrum, as they increase operational efficiency by embedding technology into diagnosis and health management [35-37]. Such steps promise a future in which healthcare is more evidence-based, accessible and efficient, and in which care becomes preventive rather than reactive, reaching individuals before unhealthy habits lead to disease. With the advancement of technology, Smart Healthcare applications have considerable potential and are enabling a new generation of healthcare solutions. The promise of improved diagnostic capabilities[36] and safer, more effective treatment from intelligent healthcare devices is great but a number of hurdles remain. Protecting patient data[37]: Given that these devices acquire clinically relevant medical information[38], ensuring the privacy and security of protected health information (PHI)[39-40] is paramount. Other considerations are ensuring the devices meet regulatory compliance and interfacing with existing healthcare systems to ensure seamless integration into the healthcare ecosystem. When a patient is monitored after leaving the hospital [41], clinicians gain better oversight of the patient's vital signs, and remote monitoring can help ensure that the patient follows the prevention plan by taking medications on time and exercising, which can reduce readmission rates and emergency visits [42]. The convergence of IoT [43], artificial intelligence (AI), big data analytics [44] and cloud computing [45] defines the emerging Health 6.0 era in the healthcare industry.

2. UTILIZATION OF IOT AND DEEP LEARNING IN SMART HEALTHCARE 6.0

IoT combined with machine learning supports a wide range of healthcare applications [46]. Applications range from tracking sleep and physical activity to monitoring cardiac rhythm, automatic fall detection giving a machine learning based holistic view on an individual health. Additionally, this data-driven approach offers healthcare providers insights they can act upon to enable them to identify when fast interventions[47] are required and to design personalized treatment programs [48]. However, some challenges must be addressed to extend the benefits of this practice. Since these are highly sensitive health data that is being recorded and analyzed, it is one of the most critical aspects to ensure security in its collection[49]. This requires regulatory compliance and the use of encryption. Organizations need to ensure they are in compliance with the law[50-52], which includes implementing transparent policy regarding data security for all patient information stored on-premises or within a cloud storage service. Improving machine learning algorithms to reduce false positives and account for individual differences, on the other hand[53]; will increase precision and performance of insights produced. The use of machine learning based methods for tracking human activity has a long history in

healthcare informatics. At the intersection of health and technology, such methods enable personalized, proactive monitoring and management that improve patient outcomes. When hardware is offered as a service, collecting sufficient data from many users raises persistent privacy concerns. Tracking users across many locations amounts to continuous monitoring of their daily routines, and the benefits of this form of monitoring may not outweigh its intrusiveness. The legitimacy and defense of individual rights[54-56] should be taken into account at the most fundamental level. Going a step further, however, individuals should be able to accept healthcare services that are seamlessly embedded in their everyday living environments. Only when monitoring offers the user a comfortable life and meets their needs and wants is this conceivable. Thoughts about security are necessary, but it is much more crucial to concentrate on the patient's preferences and create products that cater to those preferences[57-59]. Numerous services are presently offered that concentrate on smart gadgets, but the ultimate objective for people using these technologies is their own health and desires, not the device and its "smartness" in and of itself. Rather than making people more dependent on technology as machines become smarter, systems should be designed so that smart devices and related technologies improve users' wellbeing and quality of life. Only when a device's unique intelligence successfully connects users with the environment around them and focuses on human desires can this be achieved cost-effectively [60-62].

Nevertheless, the implementation of smart healthcare is not without challenges. Data security and patient privacy remain paramount concerns[63], necessitating robust cybersecurity measures[64] to safeguard sensitive medical information[65]. Additionally, interoperability issues between various healthcare technologies and systems must be addressed to ensure seamless data exchange and communication[66-68]. Smart healthcare represents a transformative shift in how healthcare is delivered and managed. By leveraging technology and data-driven insights, it holds the promise of improving patient outcomes[69-71], enhancing operational efficiency, and making healthcare more accessible and personalized than ever before. As the world continues to embrace digital innovation, smart healthcare is poised to revolutionize the industry and pave the way for a healthier and more connected future. Personal health information is being actively collected, analyzed[72], and used for medical services through platform research. In the realm of medical information and IoT-based medical devices, there is a movement toward creating standards for technology and information integration[73] that may be widely used. Applying existing standards based on usage is challenging for makers of smart wearables because they cover a wide range of technological fields. To adapt to standards more rapidly, different use cases for medical information and devices are being created. Some organizations provide a standardized application method and an open platform [74] customized to each use case, and some of these groups are developing standards for smart clothing [75]. Although IoT-based healthcare in everyday living spaces minimizes direct human interaction, it must remain a human-friendly environment. The existing regulatory framework mandates that subjects give their active, informed consent before any data collection or use in those spaces can take place. 'Lifelog data' is a term used to describe data that typically uses wearable technology or mobile devices to capture and chronicle an individual's life[76]. However, there are no separate regulations for lifelog data, the line between personally identifiable data and non-personally identifiable data is hazy, and there are still a number of legal accountability issues to resolve. A tailored service requires information gathered from various areas, thus various acts and rules must be taken into account since there is no one universal legislation for such services[77].

The smart health paradigm is also aiding the progress of quality initiatives. Access to up-to-date information allows administrators to keep tabs on essential performance indicators, monitor patient safety protocols and continually improve upon treatment quality using evidence-based approaches. Automated reporting technologies [78], embedded in continuous improvement programs, help healthcare institutions remain compliant with regulatory requirements and detect deviations early. The move to smart health, however, is far from easy. It faces three main barriers: data protection, which requires multiple layers of security; interoperability, which requires common standards so that systems can exchange data; and workforce readiness, which requires structured training to build staff capacity. Close collaboration among technology experts, policymakers and healthcare practitioners will be essential for a smooth transition to the smart health ecosystem. The introduction of smart health technologies in the management and care practices is a major leap towards making healthcare more efficient, patient-focused and data-driven. With the power of AI, IoT and data analytics healthcare organizations can change how they allocate resources, handle patient engagement, quality management and possibly even service delivery. Healthcare administration is likely to drive this evolution by using smart health technologies more adeptly, responsively and creatively. The future of the healthcare sector is related to data and much data can be obtained from various IoT devices[79]. Utilizing big data analytics along with AI algorithms for processing huge amounts of IoT device-generated raw data to identify trends, patterns and relationships. The resulting data-driven strategies focus on disease discovery, personalised therapeutic interventions and trend forecasting. Also, artificial intelligence can help healthcare professionals more quickly and accurately diagnose medical imaging (X-ray or MRI) when this technology is combined with diagnostics tools [80], [82]. Nevertheless, applying IoT in healthcare can have challenges and constraints as well. As IoT devices are mostly networked, data security and patient privacy should be a top priority to

avoid unauthorized access attempts or even leakage of health record information. To protect all this sensitive patient information, healthcare institutions need to implement strong cybersecurity measures such as encryption and access controls.

Interoperability is an important consideration in IoT, as many devices and platforms must be able to communicate with each other while cohesively linking into existing healthcare solutions. Efficient standardization and open data exchange protocols are required to ensure the compatibility and continued operation of IoT devices across different healthcare environments. This convergence of IoT and healthcare can bring a disruptive change in the functioning of entire health ecosystem. By enabling remote patient monitoring, promoting preventative treatment and improving operational efficiency as well as offering data-driven insights - the Internet of Things (IoT) is already changing healthcare. The result is turning healthcare into a proactive, individualised and economic system. Although challenges remain, the benefits of IoT in healthcare are substantial, pointing to a future of more accessible and effective care tailored to patient needs. Despite the ongoing proliferation of technology, the full potential of IoT in healthcare has not yet been realized. Nevertheless, current deployments offer a view of a future where medical services become networked and tailored to individual patients.

3. SMART HOSPITAL: ADVANCED SOLUTION TO MANAGE THE HEALTHCARE AND SERVICE CENTRED PATIENT IN FUTURE

Smart Hospital indicates an evolutionary form of health administration in which the management and treatment processes are designed to adapt automatically to patient and operational needs. This section discusses the transformative potential of Smart Hospitals, from what constitutes a smart hospital to its building blocks, benefits, challenges and future implications in healthcare. Drawing on deployments reported in the literature, we consider the transformative role that Smart Hospitals play across patient care, operational efficiency, and healthcare delivery. Technology has evolved, bringing up the Smart Hospitals that use IoTs, artificial intelligence (AI), data analytics & automation to establish a connected and streamlined arena in healthcare. A smart hospital typically comprises the following interconnected components:

1. IoT enabled healthcare equipment: Implementing various IoT devices to enable real-time patient monitoring, asset tracking and data collection
2. Electronic Health Records (EHR) Systems: These systems allow for patient records to be centralized and digitized in manner that can only be accessed by authorized healthcare practitioners
3. AI-Powered Decision Support: Machine learning algorithms assist doctors in diagnosing medical conditions, planning treatments and performing predictive analytics.
4. Patient-Centric Applications: Mobile applications and wearables designed to improve patient engagement and support tasks such as appointment scheduling.
5. Data Analytics and Insights: Using big data analysis to uncover trends, optimize resource allocation and improve healthcare.

3.1 Benefits and Challenges of Smart Hospitals

Patient care improvement: benefits to patients with real-time monitoring, personalized treatment plans and increased communication between the patient and healthcare providers.

1. Operational Efficiency: The deployment of robotic process automation for administrative tasks, optimized workflows and resource management.
2. Data Analytics: It is used to drive evidence-based decision-making and more proactive healthcare management.
3. Improved Patient Experience: Applications and services designed with patients in mind that cater to patient needs, thus enabling better engagement and ease of use and enhancing their overall healthcare experience
4. Sustainability and Cost Savings: Energy-efficient infrastructure and reduced paper usage, which help to lower operational costs.

3.2 Challenges and Important Considerations

1. Security and privacy of data: Keeping all patient records safe from digital threats and ensuring that patient health information is always protected according to the existing data protection law
2. Interoperability: ensuring that each system or device communicates smoothly and effectively with the others.
3. Workforce Training: Equipping healthcare workers with the requisite skills to adequately use and manage smart technologies.

4. Initial Investment: The cost of setting up and maintaining the infrastructure and technology needed to operate a Smart Hospital.

Technology is the main enabler of Smart Hospitals, and its advance is expected to bring new solutions, better patient outcomes and new business models in healthcare. Smart Hospitals represent a new and progressive method of administration & management, which is driven by value-based care systems that are being increasingly offered in the health sector. The key elements of successful smart hospitals include accelerated decision-making and an improved patient care experience at lower cost with better outcomes, although implementing these innovations remains challenging. Beyond patient monitoring, the data generated by connected healthcare systems can also support clinical research. Large, continuously collected datasets from IoT devices and electronic health records, combined with machine learning analysis, can help identify biomarkers, stratify patients and evaluate treatment responses, supporting the move towards personalized medicine [81].

The adoption of Smart Healthcare can bring a vast impact on patients' outcomes and delivery healthcare. With it come a number of complex legal challenges that will need to be negotiated carefully to protect the rights of patients, ensure data privacy and address ethical dilemmas. A key legal hurdle arises from smart healthcare's reliance on the collection, storage and analysis of sensitive patient data, such as medical records, personal health data and biometric information, which brings privacy and security issues to the fore. The most important measures are robust data encryption, access controls and compliance with confidentiality requirements (e.g., the GDPR in Europe or HIPAA in the US), which protect patients' privacy from unauthorized users. Consent surrounding smart healthcare is a complex area to navigate with an increasing range of technologies and data analytics systems in use, and researchers are stressing the need for informed patient consent. Patients must understand exactly how their data are being used, who will have access to it and what its implications might be. Healthcare professionals must therefore make certain that patients are well-informed and afforded the ability to opt into - or out of - being data subjects. The incorporation of AI, machine learning and autonomous systems in health care gives rise to questions regarding liability and responsibility, namely who is responsible for technical errors or their potential negative consequences [83]. When it comes to the use of technology in medical decision-making or interventions, establishing responsibility and accountability is a legal challenge which requires clear frameworks and standards.

Medical Devices Regulation: A wide range of innovative healthcare solutions include medical devices, wearables and digital health applications. Often, these technologies need regulatory approval to ensure they are safe and effective. Navigating the regulatory landscape around medical devices, especially in situations where software tweaks can influence their behavior is a complex process.

In smart healthcare systems, many devices and platforms need to interoperate with various providers for the purpose of exchanging health information. Making data available and still in compliance with stricter rules is not an easy activity. The key to unlocking the value of health data is in establishing standards as well as protocols that allow for seamless exchange but maintain patient privacy.
Applying AI and machine learning algorithms in medical decision-making raises ethical concerns, especially given that they are often trained on historical data which may not always be free from bias. In order to prevent unfair outcomes, transparency, fairness and accountability need to be a priority in algorithms. Telemedicine applications are also subject to complex regulation, including licensure requirements that differ within and between jurisdictions and rules on reimbursement for remotely delivered care, all of which vary by location.
The ownership of data created by smart healthcare systems may be the subject of dispute, especially when various parties are involved - patients or citizens, health care providers and technology corporations. Key to this is defining Data Ownership and ensuring that IP issues are resolved. Addressing these legal barriers requires a concerted effort and partnership among healthcare providers, technology developers, policymakers, and lawyers. That means setting specific rules, standards and regulations that strike the right balance between innovation on one hand and patient rights/safety on the other is key to ensuring smart healthcare can be effectively integrated into existing healthcare systems.

4. CRITICAL ASSESSMENT OF INTERNATIONAL HEALTHCARE ADMINISTRATION AND THE ROLE OF GOVERNMENT

The skills and knowledge of healthcare administration are essential in maintaining, managing, monitoring the systems that serve citizens continuously. Government policies are key drivers of healthcare through rules, funding allocation and the enforcement of standards, which together determine the performance of health systems. This section examines the governance practices followed by different governments to achieve effective healthcare administration and service delivery.

Governments have several key roles in healthcare administration:
Regulation and Standards: Governments set the regulatory framework, standards and licensure requirements for various healthcare facilities, professions and services.
Funding and Resource Allocation: Governments allocate funding, budgets and resources to ensure equitable distribution and fair access for all social groups, including the availability of medical services and physical facilities in each region.
Planning and Policy Development: Governments develop healthcare policies, strategies and subsector development plans that address public health concerns and societal needs [31]
Healthcare Delivery Oversight: Governments monitor and evaluate healthcare delivery to ensure compliance with regulations, efficiency and patient safety.

4.1 Government approaches and healthcare systems

- Universal Healthcare: Countries such as Canada, the United Kingdom and Australia use government-funded universal healthcare, in which the government provides essential health services to all residents.
- Multi-Payer Systems: In contrast, Germany and Switzerland use multi-payer systems in which public funds coexist with private insurers that compete to offer a range of healthcare options.
- System administered by the Government: In countries such as Cuba, healthcare is state-administered, meaning that the state has primary authority over both healthcare services and facilities.
- Hybrid Model: Combines elements of public and private healthcare, creating a complex structure with differing levels of government involvement, as in the United States.

4.2 Obstacles and Resolutions

- Traditional Mechanisms for Funding and the Allocation of Resources: The need to balance healthcare spending with other public goals is driving innovative approaches to funding health services and to resource allocation strategies that are both efficient and equitable.
- Healthcare Access Disparities: Governments address disparities in healthcare access through policies that ensure a just distribution of resources, especially in marginalized areas.
- Quality Assurance: To maintain and improve the quality of healthcare, governments use quality assurance mechanisms such as accreditation standards and regulatory bodies.
- Efforts to alleviate the pressures on healthcare stemming from aging demographics will necessitate extensive planning as well as targeted geriatric services and preventive interventions [17].

4.3 Overview of Representative Cases

- United Kingdom, National Health Service (NHS): one of the pioneers of universal healthcare, providing comprehensive treatment to all residents.
- Germany: a multi-payer social health insurance system based on the principle of solidarity and focused on quality healthcare.
- Japan, Universal Health Coverage: a government-based model whose goal is to ensure quality health services that are affordable and accessible for citizens.

5. CONCLUSION AND FUTURE IMPLICATIONS

This paper reviewed how IoT, AI and data analytics are shaping smart healthcare and Smart Hospitals in the Health 6.0 era. Smart healthcare technologies must be designed around users' needs; the smart technology sector currently offers a variety of added features, but they do not always align with what users value. Smart healthcare is relevant for the enhancement of safe, effective, patient-centered, timely, efficient, and equitable healthcare quality. Until such alignment is achieved, smart technology cannot significantly improve the quality of healthcare. Although there are many smart devices (such as smart watches), not all of them meet users' needs or track the user's health (such as heart rate, activity, stress level, mood, etc.). Wearable, embedded, and touchless smart devices and technologies are restricted by the capabilities of their sensors and hardware. Therefore, it is crucial to consider what

categories of smart devices are best suited to meeting users' health needs. The functions of smart gadgets should be debated in light of their sensors and physical attributes, users' actions in their environments, and peoples' values and preferences at any given time, particularly with regard to good health. Establishing the functions of smart gadgets and their current state will help us identify any gaps in the provision of continuous health services in living spaces. Personal genomes, clinical data, behavioral data, lifelogs, and health insurance are just a few of the several types of information and services needed for healthcare in the life space. Smart technology must be connected to and integrated with both current and future healthcare services in order to collect all the necessary healthcare data. All healthcare services for living spaces should be integrated and interfaced, including data collecting and analysis, standards, and regulatory considerations. In order for smart gadgets to be more successfully integrated into everyday healthcare, research on this topic is urgently needed.

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Conflicts of Interest

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