The Use of IoT in Healthcare and Medical Research

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Abstract- The purpose of this article is to provide an outline of some of the ramifications that the Internet of Things will have on the healthcare industry. The expansion of IoT-based solutions makes it impossible for the healthcare industry to operate outside of this paradigm. The purpose of this research is to present some potential avenues that may be pursued in order to realise a worldwide link between the Internet of Things (IoT) and the medical settings. Everyone, from electrical engineers to data engineers, faces a significant obstacle in the form of the imperative to integrate everything into a global setting.This transformation is changing the way we think about healthcare, from the tiniest sensors to the most extensive data sets that can be gathered.

Indexed Terms- Internet of Things, healthcare, medical environments, sensors.

I. INTRODUCTION

When individuals speak to the "Internet of Things," they might be referring to any one of a wide variety of distinct ideas, systems, protocols, or programmes. It is possible to conceptualise it as a network of things that interact with one another through the internet. Things may be traditional, physical goods that have had internet of things capability added to them, or they can be lone gadgets that are part of the internet of things. The Internet of Things is built on physical objects, which provide its foundation, while data constitutes its supporting structure. Devices and assets connected to the Internet of Things often have electronic components and software placed in them in order to collect, organise, and distribute data. Kevin Ashton is credited with having first conceptualised the term "Internet of Things." In the late 1990s, he examined the prospect of using radio frequency identification, often known as RFID, which is a technology that enables minute radio frequency tags to be attached to a broad variety of goods. These tags may store data in a format that is simple to retrieve and can be read from a considerable distance.

It is possible to enhance supply management and even act as a deterrent to theft by having the capacity to trace the locations of an item, whether it be a little sticker or a specialised label enclosed in a plastic container. This ability may be used in any instance. The use of RFID tags similar to this one is becoming more popular in the commercial sector. During his explanation of the concept that underlies his creation, Kevin Ashton also made use of the phrase "Internet of Things." He has forecasted in the past that the Internet of Things will one day be able to provide a digital representation for every physical thing in the whole planet. Radio frequency identification (RFID) technology can be found almost wherever people travel these days; it's almost impossible to avoid encountering it. Manufacturing facilities that deal with the complex production of automobiles and home appliances (such as refrigerators and washing machines) make significant use of this technology in the automation of industrial processes. These facilities include refrigerator and washing machine manufacturing facilities. Some libraries have begun to implement RFID technology in order to expedite inventory and the search for books, automate the distribution of books, and assist in the prevention of theft. The Vatican Library is an example of this kind of library; it has more than two million copies of various books in its collection. The Vatican Library has a collection that contains more than two million books and other printed works. Over seven hundred of the most significant libraries in the world are either currently using this technology or are in the process of adopting it [2, 3].

A growing number of nations are starting to include RFID chips into their newest versions of passports as well. Documents such as electronic passports and biometric passports are examples of such travel documents. The information that is printed on a paper

passport is also stored on a chip that is included in an electronic passport. This technology is "taking root" in the medical world at an incredibly quick rate. Wristbands with radio frequency identification (RFID), for example, are worn by mothers and newborns in hospitals to facilitate the matching process. Conventional hospitals often make use of them in order to monitor the locations of patients who need treatment at all hours of the day and night. An original idea for a wireless sensor network was presented [4], and it involves establishing a connection between a tracker and a heart rate monitor in order to monitor and control the position and movement of items.

The present notion of the Internet of Things is founded on the interaction that occurs between devices such as these and other technologies like as GPS, mobile phones, social networks, cloud computing, and big data analytics. Since the 2000s, when there was a significant growth in the number of devices that were linked to the internet, there has been an active evolution in the path that Internet of Things will take in the future. As a result of the Internet of Things' dependence on vast amounts of big data, users face the risk of having their personally identifiable information made public. The General Data Protection rule, often known as GDPR, is a regulation that was only recently put into effect, and its major purpose is to safeguard the privacy and personal information of customers. Alexia Kounoudes and her colleagues investigated the challenges associated with implementing the rules of GDPR to the internet of things in their study. The writers looked into the previous study that had been done on the subject of user privacy and did comprehensive research on it.

When working with the Internet of Things (IoT), it is absolutely necessary to keep in mind the General Principles for Human G20, the AI Guidelines of the G20, and the European Commission's Coordination Plan and Ethical Recommendations on AI Reliability. All of these documents were developed by the G20. The Organisation for Economic Co-operation and Development (OECD) is responsible for the development of these recommendations. To be more specific, one should adhere to the following five key concepts. values and justice that place an emphasis on people rather than goods; sustained progress and prosperity; transparency and honesty; dependability, safety, and security; and individual responsibility. The Internet of Things necessitates the creation of a specialised setting to ensure uninterrupted and, as a result, high-quality work. [5,6] This setting must consist of directly distinct "smart" devices that are outfitted with sensors, network access, and the ability to transmit information, as well as platforms for controlling the network, devices, and applications. This system is incapable of functioning properly without at least one of these components being present. It is necessary for corporations, mobile and Internet carriers, governments, and even regular consumers to work closely together in order to fully exploit the possibilities offered by the Internet of Things (IoT). This chapter's objective is to investigate the foundation of IoT in the healthcare system, with a focus on the application of IoT technologies to the rapidly developing field of personalised medicine. It examines the most recent and cutting-edge IoT-derived methodologies, as well as some well-known cases in the health field. In addition, this study focuses on the technical, ethical, and budgetary restrictions that must be overcome in order to establish a more effective medical system that can detect and diagnose illnesses at an earlier stage. Innovative healthcare systems might be put to good use by providers of medical treatment by delivering the appropriate data on the appropriate patients at the appropriate time, which would allow for the rapid and effective management of medical issues. In this chapter, we explore the role of Internet of Things technologies in health as well as some of the applications that have been developed for them. After that, we provide a few selected medical instances that illustrate an Internet of Things-driven healthcare system, and then we analyse the potential difficulties that may arise when using these technologies in the medical field.[7,8]

- IoT and Healthcare

One use of the Internet of Things that is both necessary and beneficial is in the medical field. Because of the Internet of Things, qualified medical professionals may now provide patients help through the internet. Handheld health monitors that are powered by the Internet of Things (IoT) will cut the amount of time that passes in between doctor's

appointments by a significant amount. You will be able to personalise a treatment plan for each patient by taking into account their specific requirements and current state of health with the assistance of the Internet of Things (IoT). By employing portable sensors, medical staff are able to monitor the health of their patients from a distance and react immediately to any changes that may occur.[9,10]

On the other hand, real-time measurements need a connection to the internet that is always stable and does not experience any interruptions. Despite the fast expansion of IoT in the healthcare sector, a number of medical specialties have not yet accepted it to the extent that would allow them to realise its full potential. Before effective internet applications for conventional medicine can be created, there are a lot of obstacles that need to be conquered first. It is expected that over the course of the next several years, the Internet of Things will play a role in the process of attracting a bigger number of persons who are interested in engaging in medical research. When it comes to making judgements that are both informed and individualised, modern medical practitioners are challenged by the necessity of gathering a significant quantity of big data as well as their analysis and interpretation. This requires a significant investment of both time and effort. These new technologies of the IoT have the potential to speed up and make this procedure easier. There has been a significant increase in the volume of medical data that has been digitised recently due to the widespread implementation of electronic health registration. It will take a significant amount of time to carefully examine and evaluate all of this data. In addition, it is necessary to provide training for the medical personnel on the AI-based technology that is closely related with the internet of things (IoT).[11] It's possible that medical professionals may be able to deliver more personalised care for their patients with the aid of digital technologies like the internet of things and artificial intelligence. These technological advancements make it feasible to manage a vastly greater volume of data, which can then be collected, analysed, and used in order to maintain tighter tabs on the progression of a disease or other activity. It is possible that improvements in healthcare administration might be brought about as a result of a successful combination of the knowledge obtained through human practises with the opportunities presented by contemporary diagnostic, data gathering, and analytical techniques. The Internet of Things is broken down into its component parts and explained with reference to the healthcare industry in Figure 1. The Internet of Things will pave the way for the development of future technology that is network-enabled.

gadgets that are wearable and portable will be used in these technologies. These gadgets will have the ability to trigger, detect, synergize, and connect with other comparable material that is available through the internet. The generation of data, its use, and its distribution are all being significantly influenced by the Internet of Things.[12] The vast majority of individuals use these systems on a consistent basis to keep track of the food they eat, the amount of sleep they get, their vital signs, the amount of exercise they do, and other aspects of their physical status. On the other hand, Internet of Things technologies occasionally receive and act on ecological data, which may have an effect on an individual's health. As a consequence of the ultimate deployment of this interoperability, a new manufacturing line for alternative medical treatments was initiated.gadgets that are wearable and portable will be used in these technologies. These gadgets will have the ability to trigger, detect, synergize, and connect with other comparable material that is available through the internet. The generation of data, its use, and its distribution are all being significantly influenced by the Internet of Things.[12] The vast majority of individuals use these systems on a consistent basis to keep track of the food they eat, the amount of sleep they get, their vital signs, the amount of exercise they do, and other aspects of their physical status. On the other hand, Internet of Things technologies occasionally receive and act on ecological data, which may have an effect on an individual's health. As a consequence of the ultimate deployment of this interoperability, a new manufacturing line for alternative medical treatments was initiated.

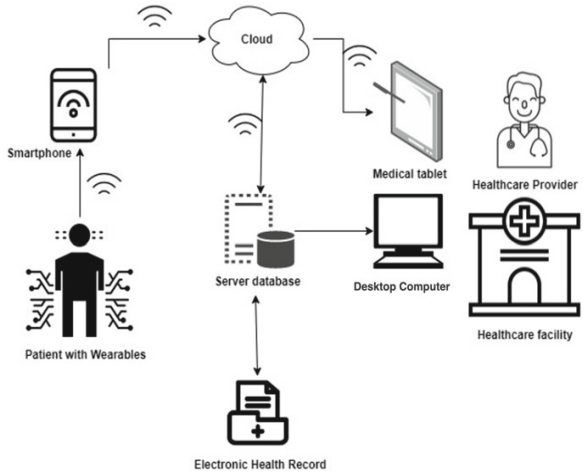

Fig.1 The concept of IoT in healthcare [13]

- Applications of IoT in Healthcare

The Internet of Things has the potential to make significant contributions to medical research, clinical practise, and the management of patients. In a more general sense, it has a variety of applications relating to the insurance industry as well as the industrial sector. The contribution of IoT may be seen in each of the aforementioned scenarios via the lens of one of these four concepts. The first concept is the collecting of data, which is assisted by networked devices like as sensors, monitors, detectors, equators, and cameras. The second principle is the organisation of the data collected. The transformation of data is the second guiding concept. In light of the above, it is of the utmost importance to point out that the input of sensors and other associated devices is in the form of analogue data, which needs to be converted into digital data before it can be subjected to further processing. The third principle is the storage of data, which is often accomplished through the use of a system that is hosted on the cloud. The processing of data by utilising various sophisticated analytics techniques is the fourth principle. This ultimately results in the users receiving the information that is required for effective decision-making. The aforementioned concepts are already present in the majority of facets of healthcare, ranging from patient records that are handwritten to databases that are networked among laboratories.[14,15] They are distinct in the setting of the internet of things due to the fact that the flow of data is continuous and the impact of decisions based on the internet of things might be immediate. Wearable technology makes up the bulk of the Internet of Things infrastructure for patients. Depending on the patient's medical history and the parameters that need to be monitored, wearables may include glucose level monitors, oxygen saturation monitors, blood pressure monitors, pulse/heart rate monitors, and other similar devices. These gadgets make it possible to provide individualised care in the event that the patient's health suddenly worsens or continues to deteriorate over time. When linked to fitness tracking and calorie counting software, as well as appointment and referral management systems, they are also capable of performing the function of reminders. The Internet of Things makes it possible for doctors to maintain a link in real time with their patients, their colleagues, and their medical facility or laboratory. It is possible to alert a cardiologist about an arrhythmia that is harming one of his patients, and it is also possible to inform a diabetologist about hypoglycemia that is endangering one of his patients. Patients are able to receive quick medical counsel and assistance, regardless of the circumstance. The adherence of patients can be evaluated by their physicians. [16,40] In the event that patients fail to adhere to their therapy, it is not only a problem of the outcome (for example, a rise in blood pressure), but it may also be an issue of the device monitoring. With this information in hand, pillboxes are able to be tracked by monitoring the number of times per day that they are opened. There is mounting evidence that the statistics produced by IoT devices can help clinicians choose the most effective course of therapy and care approach for their individual patients. This makes an important contribution to the field of personalised healthcare. These vast datasets on a broader scale might serve as the foundation for future research relating therapy to outcomes. Larger-scale Incubators for Internet of Things applications can be found in places like hospitals and research centres. This is a result of the heavy workload and variable nature of the data that has to be processed at these institutions, the responsibility that these organisations are expected to shoulder, as well as the financing that these institutions receive. In addition to monitoring the health of inpatients and outpatients, which was discussed in the part that came before this one, hospitals and labs may make use of the internet of things in order to safeguard equipment such as wheelchairs, defibrillators, nebulizers, and oxygen

pumps. This topic was covered in the section that came before this one. In addition, research facilities have the capability to monitor the evolution of experimental activity, the distribution of equipment, and the availability of resources in a way that is both continuous and time-consuming. At some point in the not-too-distant future, communication and sensor devices will evolve into multi-faceted information technology solutions that may be used in a variety of settings. The increasing capabilities of the Internet of Things (IoT) have made it simpler for academics and medical professionals to conceptualise novel approaches to patient care. [17]The research project that is connected to the Internet of Things (IoT) is essential due to the fact that it has crucial relevance. It entails offering preventive care and other services in an effective manner at a higher quality and at a reduced cost. The Internet of Things is progressively gaining popularity as a distinct area of study in a range of academic and commercial sectors, most notably in the field of medicine. This trend may be attributed to a number of factors. In a way that is rather remarkable, the IoT-derived approaches are moving health care away from the old hub-centered system and towards more personalised healthcare systems. This is happening in tandem with the spectacular spread of smartphones and wearable gadgets. In recent years, e-health has become increasingly utilised to deliver individualised medical services in response to the growing demand for healthcare among individuals. The Internet of Things represents a significant advancement in this era of big data, endorsing a variety of relevant technical tools in order to maximise service efficiency. In today's world, the healthcare industry makes use of IoT data analytics as a consumer data source in order to discover more information, diagnose diseases at an earlier stage, and evaluate necessary requirements for improved life quality. In the end, the rapidly increasing requirement for an upgraded healthcare system in a timely manner. [18] IoT devices are able to instantaneously gather and share data with other cloud-based platforms, which makes it possible to collect, store, and analyse an enormous amount of data. The Internet of Things devices would be useful for computerising businesses and for tracking faraway objects.

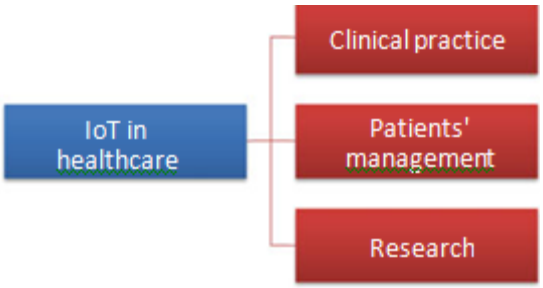

Fig.2Key uses of the Internet of Things in the medical industry

regarding the neighbourhood and its environs. Applications of the internet of things in medicine have great potential because of their capacity to expand patients' access to care, lower associated costs, and most importantly, improve their quality of life. Applications of the internet of things have the potential to improve operations in a variety of fields, including healthcare and insurance systems. The Internet of Things might be used for the storing of data, the evaluation of products, the evaluation of patients, and the provision of speedier compensation services. [19] The primary use of the Internet of Things in the medical field is seen in Figure 2. However, such applications may run into significant legal hurdles due to the data protection policy as well as the involvement of financial interests in the management of such information. Both of these issues might occur simultaneously.[41]

- Selected Cases of Using IoT in Healthcare

Today, mobile applications and wearable technologies allow for the monitoring of symptoms, medical education, fitness, as well as the collaborative management of diseases and coherent treatment. The use of analytics software packages has the ability to dramatically enhance the quality of the data interpretation as well as drastically minimise the amount of time necessary to reassemble the data that has been produced. The expansion of electronic processes into the realms of medical, business, and time-selection will be aided by the insights acquired from the study of big data. Because the world's population is getting older at a faster rate, it is essential to improve understanding and interpretation of data regarding health and well-being, minimising chronic and diet-derived diseases, enhancing mental skills, boosting mental health, and improving lifestyle

choices. Despite the fact that it is impossible to cover each and every potential application of the Internet of Things to the healthcare business, we will offer an overview of the most significant healthcare applications of the Internet of Things. This will be done in order to better serve our audience. It is abundantly clear after reviewing the scientific literature and a few commercial resources that the Internet of Things will soon play an important part in the management of exacerbations of acute conditions, the treatment of cancer, patient-driven self-assessment procedures, drug delivery and adherence monitoring, and the treatment of mental health conditions. This is because the Internet of Things will soon be able to monitor patients' adherence to their medications. [20,21] Clinical investigations using wearables designed for the aim of cancer care (CC) have been carried out in the past. The findings of a randomised clinical study were reported at the 2018 Annual Meeting of the American Society of Clinical Oncology (ASCO). In addition to being tracked using software that gathered symptoms and sent frequent and urgent updates to the patients' doctors, the patients who participated in the study for head and neck cancer were also monitored with a blood pressure cuff and a scale that were both equipped with Bluetooth technology.

The study was focused on patients with head and neck cancer. About four hundred patients took part in the trial; those patients who utilised the IoT-based system reported less symptoms than those patients in the control group, who were examined physically once per week. Diabetes is a model illness that may be used to evaluate self-monitoring and treatment adherence in a variety of settings, such as oral pharmacotherapy, injectable insulin, blood glucose testing, and blood pressure monitoring, to name a few. Continuous glucose monitoring based on the internet of things may be implemented on a wide variety of already available devices. [22,23] Although patients with type 1 diabetes mellitus (T1D) are most likely to require continuous monitoring and quick action, there is mounting evidence to suggest that people with type 2 diabetes can benefit from more frequent monitoring or even continual monitoring in order to reduce their risk of problems. Patients who have diabetes mellitus (DM) may benefit from using smart insulin pens as one of the important methods to evaluate treatment adherence. Even though the currently available devices are intended for insulin injections, it is possible that similar devices may be used for pillboxes. These kinds of wearables are now able to communicate with apps on smartphones and are routinely evaluated by medical professionals. By incorporating these modes into an Internet of Things framework, clinicians might be alerted to patients who are delaying treatment sooner and take appropriate action. In the treatment of type 1 diabetes, the development of closed-loop (automatic) insulin delivery devices has been long awaited. The implementation of such devices into clinical practise has been hampered by issues that may be related to regulatory oversight and management. In light of the fact that the Internet of Things (IoT) has the potential to make a substantial contribution towards overcoming such challenges, several lobbying efforts on the part of medical professionals and patient networks have already been spotted. Patients with type 1 diabetes who are at risk of diabetic ketoacidosis may benefit greatly from using an automated and IoT-secured closed-loop system, despite the fact that a number of actions must first be done in this respect. Asthma, rather than diabetes, is a chronic ailment that has a pattern of exacerbations and presents a promising field for healthcare that is based on the internet of things. It is a tremendous burden for the hundreds of millions of individuals all over the world who are affected by it. The majority of patients are young adults who lead an active lifestyle and are interested in maintaining a high quality of life. When it comes to the early diagnosis and management of an impending exacerbation, Internet of Things devices that evaluate saturation or warn about the presence of common allergens are significant. In the same context, Internet of Things (IoT)-based inhalers might give the physicians of their patients with trustworthy information on the patients' capacity to manage the device appropriately and their level of adherence to their treatment regimens.[24,25]

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processes into the realms of medical, business, and time-selection will be aided by the insights acquired from the study of big data. Because the world's population is getting older at a faster rate, it is essential to improve understanding and interpretation of data regarding health and well-being, minimising chronic and diet-derived diseases, enhancing mental skills, boosting mental health, and improving lifestyle choices. Despite the fact that it is impossible to cover each and every potential application of the Internet of Things to the healthcare business, we will offer an overview of the most significant healthcare applications of the Internet of Things. This will be done in order to better serve our audience. It is abundantly clear after reviewing the scientific literature and a few commercial resources that the Internet of Things will soon play an important part in the management of exacerbations of acute conditions, the treatment of cancer, patient-driven self-assessment procedures, drug delivery and adherence monitoring, and the treatment of mental health conditions. This is because the Internet of Things will soon be able to monitor patients' adherence to their medications. [20,21] Clinical investigations using wearables designed for the aim of cancer care (CC) have been carried out in the past. The findings of a randomised clinical study were reported at the 2018 Annual Meeting of the American Society of Clinical Oncology (ASCO). In addition to being tracked using software that gathered symptoms and sent frequent and urgent updates to the patients' doctors, the patients who participated in the study for head and neck cancer were also monitored with a blood pressure cuff and a scale that were both equipped with Bluetooth technology.

Fig.3Several examples of the Internet of Things being used in medical settings[26]

- Challenges of IoT in Healthcare

It is anticipated that IoT would bring about a revolution in the medical industry. Nevertheless, turmoil and disagreements are necessary components of each revolution. In point of fact, the tension that exists between the technological level and the moral level is what determines how innovation is implemented. As seen in Figure 4, the difficulties associated with the Internet of Things in the medical field may be broken down into three categories: the ethical, the financial, and the technological.

- Technical Challenges

Because the Internet of Things is not yet an integral part of people's everyday lives, there are certain technical aspects to take into account. The fifth-generation cellular technology, often known as 5G, and the Internet of Things services are not yet accessible in the majority of nations. Patients aren't the only ones who don't know much about the Internet of Things (IoT); the great majority of medical professionals and researchers, too, don't have a good understanding of what it is and what it can accomplish, even outside of the context of medicine. [27,28] The aforementioned 5G issue might be regarded as the primary technological obstacle that the IoT adoption in healthcare must overcome. The deployment of 5G necessitates the installation of several antennas, which is not only expensive but also time-consuming and has been linked to potential risks to one's health. Even if there is not enough evidence to support this assertion, further study has to be carried out in order to determine whether or not the usage of 5G technology on a big scale is safe. It is possible that dealing with the worldwide ramifications of 5G, convincing politicians, and altering (with their assistance) the public opinion might require the same amount of time or even more time than safety investigations. One of the most compelling arguments in favour of implementing 5G might be the possible advantages that would result from applying the Internet of Things (IoT) in the medical field.

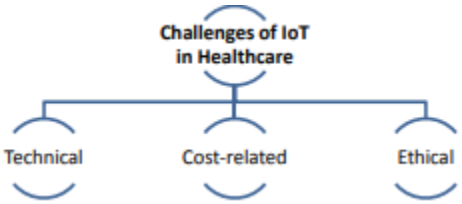

Fig. 4 IoT in health care challenges [29]

The integration of data presents the following technological obstacle to be overcome. When there are multiple sources of data, there must also be multiple devices. In the field of healthcare, there is a wide array of wearables and data collecting devices, many of which are not easily modifiable to a uniform pattern of data gathering for a variety of reasons, including budgetary and logistical constraints. Even at this late date, manufacturers have not come to a decision about the communication protocols and standards that should be used. Patients suffering from the same condition may utilise a variety of wearables, each of which may focus on either the sickness itself or the vital signs of the individual in general. Patients diagnosed with diabetes, for instance, may make use of distinctive glucose and vital signs monitoring systems, in addition to closed-loop insulin pumps of their own choosing. This accounts for at least three different kinds of data coming from the very same patient when taken together. Even if this data will, at some point in the future, be processed, doing so will take additional time. This extra time can be an issue when it comes to the care of acute diseases, and it has also been a problem when multiplied by a large number of people.

- Financial Challenges

In regard to the monetary components of the subject matter, our intention is to expound on the potential difficulties associated with cost-efficiency. [43]The Internet of Things falls under the category of apps that are used for remote medical care from a business perspective. The current budget for remote health monitoring in Europe is 10.41 billion euros, and it has grown to over 12.4 billion euros over the past few years, as reported by the International Data Corporation (IDC). When considering the construction of IoT health care, such a budget would appear to be favourable. However, many potential investors have already been dissuaded from participating due to the complexity of putting IoT into practise. Instability in the financial sector can be attributed, in part, to the engagement of third-party service providers in the process of ensuring the quality of the internet of things and the infrastructure connected with it. The empirical observations imply that both public and commercial healthcare providers would be unlikely to support the creation of an IoT healthcare network without evidence and experience from other healthcare systems or countries.[30,31,32] This is the case even if those other healthcare systems or nations were inside the same country. To be more specific, it was projected that the size of the Internet of Things healthcare sector was worth $60 billion back in 2014. By the year 2021, it is anticipated that it will have amassed a net worth value of $136 billion. It is notable that it is anticipated that the Compound Annual Growth Rate (CAGR) of IoT in healthcare will approach or even exceed 12.5% over the course of the projected period. The ability of both outsourced providers and healthcare providers to achieve and maintain an acceptable degree of understanding and collaboration will determine whether or not this upwards movement will be maintained.

The Internet of Things has the potential to lessen the monetary burden associated with providing medical care if it is put into practise. The expenses associated with healthcare are generally broken down into two categories: direct costs and indirect costs. Expenses incurred by healthcare providers are referred to as the former, whereas expenses incurred by healthcare recipients are referred to as the latter. Expenses incurred by healthcare recipients include absence from professional activity, uncompensated treatment costs, and the participation of family members or other caretakers in the treatment of the patient. Because Internet of Things (IoT) healthcare services have not yet been implemented in any major healthcare system, there is a paucity of research about the cost-effectiveness of these services. Economists have already brought to light some characteristics of the Internet of Things that will lead to a more efficient and cost-effective model of development in the healthcare industry. It is already widely accepted that the implementation of proactive asset management, inventory management, stringent quality control, optimised product packaging, and supply chain management are all necessary

conditions for achieving financial success with IoT in the healthcare industry. Nevertheless, as of right now, these ideas appear to be more industry-centered than health care-centered. In order to successfully implement them into clinical practise, economists, healthcare managers, and physicians will need to work closely together and have a profound knowledge of each other's roles.[33,46]

- Ethical Challenges

The fundamental issues at the heart of the ongoing ethical discussion over the Internet of Things in the medical field are the paradigms of data management and patient care. Concerns around informational privacy, data sharing and autonomy, data ownership and consent, and unknown value problems raise the most eyebrows when it comes to the management of sensitive health-related data. Other problematic aspects include challenges with values that are unknown. The isolating and dehumanising impacts of doctor–patient relationships, the decontextualization of health and well-being, and the potential of obtaining treatment from someone who is not a certified medical practitioner are some of the ethical red flags that arise in the context of care.

Policy decisions regarding the Internet of Things (IoT) in healthcare may be influenced by repercussions from the subject of ethics. Any relevant law should automatically adhere to universal and regional standards, such as the Universal Declaration of Human Rights and the General Data Protection Regulation (GDPR) in the European Union, respectively. These are examples of standards that are applicable on a global and regional scale. In this context, it is also anticipated that the formulation of policies would serve as a possible origin of ethical roadblocks in the way of the application of IoT in health care. Even if the GDPR is only applicable within the European Union, it can nonetheless have a significant impact on IoT research that is relevant to healthcare.[44,45]

It is vital, in order to comprehend the ethical burden, to examine certain real-life examples within the framework of the internet of things for healthcare. Sensors that follow people around at work and at home will eventually become an accepted part of daily life and may even be forgotten by the people who use them. However, the same sensors that are blending into the background will monitor any moment of their users' personal lives, including the usual variations in pulse that occur during a fight as well as joyous occasions. Sensors that detect and analyse sounds may also "overhear" a user having private talks if they are placed in the right location. Even if the users give their agreement to this monitoring for the benefit of their own health, the privacy of their family members, friends, and coworkers may be violated as a result of this surveillance.[34,35,36,47]

Researchers have already developed technologies that promise a selective memory of Internet of Things (IoT) linked sensors. To the best of our knowledge, establishing clear boundaries between what should be kept private and confidential and what is essential for patient care can be a challenging endeavour. Fights that occur on a daily basis within the family or dialogues that are held in silence about the user's questionable conduct may conceal indicators of hidden hypertension or arrhythmia. [37,48]The use of a trained physician or data scientist to determine what is significant in the event that the sensors are unable to make a selection is in and of itself a breach of a person's right to privacy.

When it comes to making potentially harmful judgements, depending solely on data that has been acquired by sensors and then picked places a significant ethical weight on the decision maker. What should be done in the event that an increase in the dosage of anticoagulation, prompted by an IoT-mediated monitoring system, results in significant bleeding in the gastrointestinal tract? One line of reasoning is that doing research on the application of sensors will result in the production of the evidence-based guidelines that are required. Despite this, it is unacceptable to put the health and lives of patients, who under normal circumstances would not be willing to take such a risk, at hazard.[49]

It is vital that the cyber security of internet-connected medical equipment and services not be ignored either. This is an absolute necessity. Both the storing of data and its processing involve the use of services that are hosted in the cloud. Hacking will continue to be a substantial issue even if all of the ethical

concerns involving the healthcare and outsourced firms that will have access to these data are resolved. It is feasible for insurance firms and HR departments to hack the biometric data and medical histories of potential workers, which can lead to applicants being treated unfairly. Under the same conditions, any other organisation or individual may, in order to prevent the decryption of pertinent information, make monetary or other demands.[38,50]

CONCLUSION

The Internet of Things brought about significant changes in the healthcare business, including increased productivity, decreased expenses, and a refocused attention on improved patient care. In the meantime, the Internet of Things is expanding from the fundamental components of automation and machine-to-machine communication to the tiniest sensors. We also take into consideration the ways in which IoT may be utilised to enhance healthcare and the ways in which IoT assists both individuals and governments in improving the day-to-day activities of individuals as well as communities. [39]Even if there are potential risks involved with disclosing someone's location, we can nonetheless provide certain permissions to individuals in order to make it possible to implement safeguards against abuse by other individuals. However, a significant amount of work need to be done before this Internet of Things technology can be utilised to its full potential. In the future, we will need to expand these applications in order to bring about the degree of health that we want to see in society.

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