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*REVIEW ARTICLE - ENGINEERING*

# The Impact of the Internet of Things (IoT) on Healthcare Delivery: A Systematic Literature Review

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**Abstract**

The Internet of Things (IoT) also has a huge impact on dramatically lowering healthcare expenses and increasing treatment outcomes. The only ways that patients could communicate with doctors before the Internet of Things were in person, over the phone, or via text. There was no feasible way for healthcare providers to assess patients' health and offer advice continuously. IoT-enabled technological equipment has made remote monitoring possible in the healthcare industry, opening opportunities to keep patients safe and healthy and empowering medical professionals to provide the best treatment possible. This review provides a comprehensive study of the literature on IoT's impact (negative or positive) on healthcare delivery and why it is difficult to implement despite its enormous benefits. Search engines (journal publishing databases) like Google Scholar, PubMed, and ScienceDirect were used to find studies on the impact of IoT-based healthcare delivery. Data were extracted from papers found, and the quality of studies that qualified for inclusion and exclusion was assessed and reported. It includes the proposed technologies' validation as well as their clinical effectiveness. The review found that the lack of government commitment to financing IoT projects is a challenge to its implementation in healthcare delivery since it involves huge capital at the beginning and its maintenance. In addition, some medical professionals are still acquainted with the old-fashioned (manual) ways of delivering their services, hence avoiding the technological approach. Despite the challenges, one noted the positive effect of IoT in healthcare delivery is that doctor-patient interactions have gotten simpler and more effective; it has also raised patient participation and satisfaction. Furthermore, remote patient monitoring shortens hospital stays and avoids readmissions by monitoring patients' health.



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**Keywords**: Impact; Internet of Things; Healthcare Delivery; Digital Health; Electronic Health.

## 1. Introduction

The globalization of economies, societal change, and other factors place new demands on health service providers globally, but at the same time, digital technologies and communication advancements give health service providers and policymakers the opportunities to improve access to, the effectiveness, the affordability, and the timeliness, of healthcare [1].

The potential of IoT technology to reduce the pressure on healthcare systems brought on by an ageing population and an increase in chronic illnesses has garnered a lot of attention in recent years [2]. Again, as proclaimed by Dhingra et al. [3], in contemporary centuries, the number of digital health services has increased exponentially and unchecked, raising questions about data privacy, ethical norms, and service quality. Currently, the healthcare system has evolved into a complex ecosystem consisting of a wide range of devices, databases, and communication technologies that work together to provide different healthcare services [4].

The right to healthcare is a fundamental right of every human being and includes anytime and anywhere accessible, available, acceptable and high-quality medical services [5]. Healthcare agencies and providers in advanced and emerging states or countries face various challenges plus the demand for great quality and equitable delivery. Universally, there are determined struggles directed at changing access, healthcare delivery, patient experiences, and health aftermaths through digital health (including eHealth, mHealth etc.) [6].

Digital health builds on the previous eHealth developments and interventions by the World Health Organization (WHO). WHO defines eHealth as the use of Information and Communication Technology (ICT) for health for instant treatment of patients, pursuing research, educating students, tracking disease and monitoring public health [7]. The latest developments led by WHO have moved from eHealth to digital health, which has an emphasis on digital consumers, with a wider range of smart devices and connected equipment being used, together with other innovative and evolving concepts such as that of IoT and the more widespread use of Artificial Intelligence (AI), big data and analytics [8].

| Nomenclature & Symbols | | | |
|---|---|---|---|
| AND | Logic AND | IoT | Internet of Things |
| AI | Artificial Intelligence | M2M | Machine-to-Machine |
| DOI | Digital Object Identifiers | mHealth | Mobile Health |
| ECG | Electrocardiogram | MS | Microsoft |
| EEG | Electroencephalogram | OR | Logic OR |
| eHealth | Electronic Health | PRISMA | Systematic Reviews and Meta-Analysis |
| EMG | Electromyogram | WHA | World Health Assembly |
| ICT | Information and Communication Technology | WHO | World Health Organization |

Digital health is understood to incorporate eHealth and mHealth and deals with issues such as scalability, replicability, interoperability, security and accessibility, and it is rooted in eHealth [3]. eHealth in the World Health Assembly's (WHA-WHA58.28) resolution is defined as the secure and cost-effective application of information and communication technologies to areas associated with health, such as healthcare, health surveillance, health literature, and health education, knowledge, and research reinforces the vision and the scope set by the resolutions in support of health systems and universal health coverage [8].

The Internet of Things (IoT) is one of the twenty-first century's fastest-growing technologies. It meets all the standards for today's needs, and it is a network architecture in which all-physical items (things) are connected via a router and exchange data. IoT is a technology that allows items to be controlled remotely over an existing network, a smart network that reduces human labor and employs an automation system to operate devices without the need for manual commands [9]. IoT's widespread use of these devices has an impact on connected systems in business, healthcare, and other industries [10].

Proactive threat mitigation and the creation of robust security solutions utilizing cutting-edge technology are urgently required. Smart IoT applications' constrained nature is a key barrier to security, which must be addressed while recommending effective security methods [11]. The two key IoT technologies are cloud computing and blockchain. However, their shortcomings in the healthcare industry are little mentioned. While blockchain may be utilized for security, it exhibits significant latency and lacks scalability, while cloud computing offers barriers regarding security and privacy, the accuracy of patient data, the opacity of infrastructure, and difficult performance monitoring [12] are a couple of the noted challenges with IoT.

The aim of this review was to identify both the negative and positive impacts of IoT in the delivery of healthcare. By referring to positive impact, we mean to look at the benefits that the health sector will derive from IoT, while the negative impact will look at the challenges that are posed by the implementation of IoT when overlooked.

The general structure of the paper is presented as follows: The Literature Search Strategy and keywords, Exclusion and inclusion criteria and the Extraction of Data have been illustrated within the material and methods in section 2. Whereas the positive/negative impact of the outcomes of the results achieved was presented in section 3. Finally, a summarized discussion and concluded remarks were addressed in sections 4 and 5, respectively.

## 2. Materials and Methods

This study of a systematic review decided to avoid poor and biased reports or work, and so chose to use the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) approach to harness the best of literature works.

PRISMA was created to aid systematic reviewers in reporting why the review was conducted, what the authors did, and what they discovered in a transparent manner [18]. The study followed the PRISMA 2020 statement, which is the current version of the PRISMA methodology and overrides the 2009 version. As claimed by Page et al., the PRISMA 2020 statement contains revised reporting guidelines that consider improvements in techniques for finding, choosing, evaluating, and synthesizing studies. To make deployment easier, the items' appearance and organizational design have been changed [18].

The study opted for the PRISMA technique because aside from the characteristics, it has other importance on the study, which includes but is not limited to assisting authors in reporting systematic reviews and meta-analyses more effectively. While it is not a tool to judge the quality of a systematic review, it is helpful for the critical evaluation of published systematic reviews (Fig. 1).

### *2.1. Literature Search Strategy and Keywords*

Renowned journal databases such as Google Scholar, operated by Google; PubMed, which is run by the National Library of Medicine and ScienceDirect, which is owned by Elsevier, were used to query for publications regarding the impact of IoT in healthcare delivery. We wanted to obtain as many papers as we could to adequately perform our systematic literature review and to prevent bias in our report. Thus, we chose the published databases for the study.

We went ahead to define the various keywords or search terms which are relevant to the topic and then distinct where (data sources, resources, etc.) and how (the criteria for selection of literature, search techniques, etc.) for the study. In generating the keywords or search terms, we based on the research question for derivation and consideration. We then considered the major synonyms and alternative spellings and then verified them against any relevant paper. Booleans such as OR and AND operators were employed, and in some cases, a double quote was used around two or three words to force a strict search.

Finally, we managed to design our search keywords for the searches in the aforementioned publication databases, which are Google Scholar, PubMed and ScienceDirect, with the following - impact OR internet of things OR healthcare delivery OR "digital health" OR "electronic health".

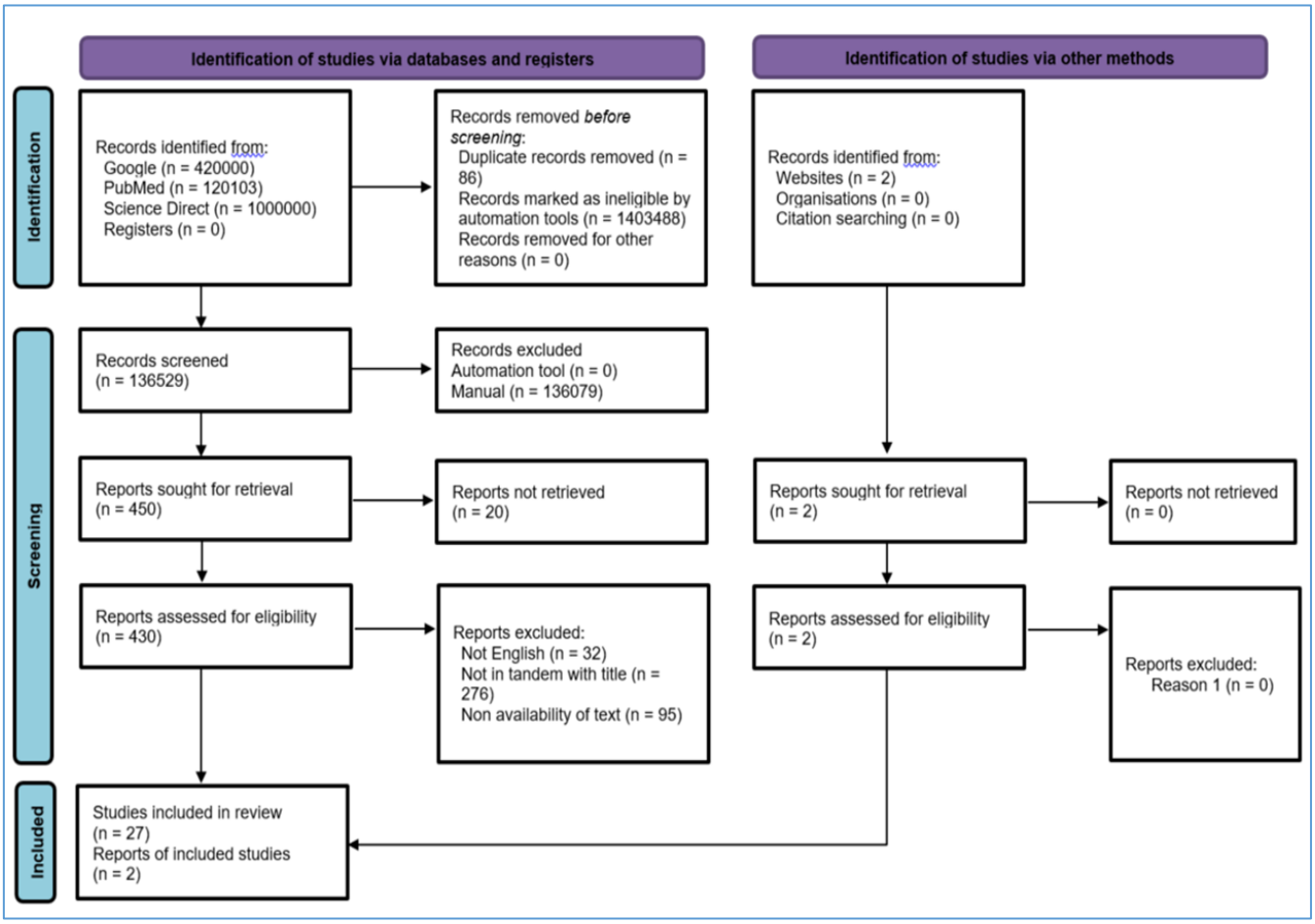


Fig. 1. PRISMA diagram showing how documents were included and excluded in the review

2.1.1. Search strategy using google scholar

When the produced keywords were used as a search phrase to access the Google Scholar database (search engine), four-hundred and twenty thousand (420,000) results, with dates ranging from 2017 to 2022, were retrieved. Since Google Scholar is more of a search engine than a publishing database, these results included a lot of grey literature. To limit the search results to only reviewed articles, we clicked the Review articles link and limited the search to only English-language articles. This produced fifty-five thousand three hundred (55,300) records while maintaining the date range.

2.1.2. Search strategy using PubMed

Again, to find literature relevant to our research issue, the same keywords defined for the study were employed in the PubMed environment. Seventy-five thousand seven-hundred and eighty-nine (75789) records of published articles were returned in total by the search. Before the search produced the results previously mentioned, the inclusion criteria of Text Availability (Abstract and Full Text), Article Type (Books and Documents, Review, and Systematic Review), Year of Publication (from 2017 to 2022) and Language (English) were employed which pulled a total of one-hundred and twenty thousand, one hundred and three (120103).

2.1.3. Search strategy using ScienceDirect

The ScienceDirect database was used to conduct our search term using our third and final search method for the investigation. One million (1000000) records were returned from the search, many of which contained articles that were unnecessary for the study's purposes. To limit the amount of these records, we applied filters to the search results. Several filters were used, including Publication Year (from 2017 to 2022), Article Type (Review and Research Articles), Publication Title (Social Science & Medicine, and Biomedicine & Pharmacotherapy), and Subject Area (Medicine and Dentistry, Engineering). Five-thousand four-hundred, and forty (5440) records were maintained after the filters stated above were applied.

*2.2. Exclusion and Inclusion Criteria*

The study did not just include or exclude papers from the search results gathered from the three sources but then went extra to manage the data pulled from the various search databases into the Mendeley Reference Manager software. We then used the software to remove duplicates from the papers downloaded into the software from various sources.

Aside from the various filtering techniques applied during the search for the publications in the various journal databases, formal criteria were additionally employed to help re-fined the publications to be reviewed.

The Exclusion criteria involved that sources, which were not within the scope of the research question, were removed from the study and they were based on such fact that those articles were focused on other IoT usages than on healthcare delivery. Another criterion was that, their full texts were not available and not even when they were searched for in some search engines e.g. on sci-hub.se using digital object identifiers (DOIs). Finally, we based on the language in which the publication was written, in which case we were only interested in those written in English.

The Inclusion criteria involved but were not limited to first including those written in English and specifically geared toward healthcare delivery, digital health, etc. Not only those written specifically for health care but those that spelt out the challenges in implementing IoT generically and the importance.

*2.3. Extraction of Data*

The Exclusion and Inclusion strategies applied to the publications retrieved from the three data sources reduced the quantity of the result to a substantial amount which was ready for onward processing by extracting vital information related to the research question and objective.

Using the Mendeley Desktop Reference Manager (v1.19.8), the publications records were exported into a comma-separated value file, which was imported into Microsoft Excel 2016. Using MS Excel, a literature review matrix was constructed to segregate the citations into common thematic areas with respect to the authors of each paper. All the papers were then reviewed based on their abstracts, conclusions, and discussions to get the appropriate data for each thematic area.

Organizing the contents extracted from these publications into themes will not only help identify the common direction of knowledge of different authors but also help in synthesizing and appreciating the focus of each article.

## 3. Results

The primary findings and conclusions from a thorough investigation into the influence of the Internet of Things (IoT) on healthcare delivery are presented in the section that follows. This study reviewed considerable literature on the impact of IoT on healthcare costs, treatment results, and relationships between patients and doctors. The goal was to evaluate the advantages and disadvantages of using IoT in healthcare and the obstacles preventing its wide implementation.

The study concentrated on the advantages of Internet of Things (IoT)-enabled technology, which has transformed healthcare by making remote patient monitoring possible. IoT has created new opportunities for enhancing patient safety, health outcomes, and the general standard of medical care by continuously monitoring patients' conditions and providing guidance in real-time. Healthcare personnel are now better equipped to deliver the best care and assistance, regardless of location, thanks to the capacity to monitor patients remotely.

This study used well-known search engines and journal publishing databases like Google Scholar, PubMed, and ScienceDirect to find relevant research papers on the effects of IoT-based healthcare delivery. To ensure strict inclusion and exclusion criteria, data were retrieved from the chosen papers, and the quality of investigations was reviewed.

Several obstacles to the application of IoT in healthcare delivery were discovered through the review of the literature. Due to the significant initial investment and continuous maintenance expenses required, one noticeable difficulty is the absence of government commitment to finance IoT initiatives. Additionally, some medical professionals continue to use manual, old-fashioned methods of providing services, which discourages the adoption of IoT technologies.

Nevertheless, the study found that IoT has number of advantageous benefits for healthcare delivery, despite these obstacles. Notably, interactions between doctors and patients have gotten easier and more efficient, which has boosted patient involvement and happiness. Furthermore, since patients' health may be carefully monitored from a distance, remote patient monitoring made possible by IoT technologies has shown promise in lowering hospital stays and eliminating needless readmissions.

The specific findings and analysis from the study, as well as the validation of suggested IoT technologies and their clinical efficacy, are covered in more detail in the next sections of this paper. The findings will provide vital information for healthcare providers, policymakers, and researchers looking to harness the potential of IoT in changing the healthcare environment. The sections will also highlight IoT's overall influence on healthcare delivery.

*3.1. Why the Need for IoT in Healthcare Delivery?*

As the population ages, chronic diseases become more prevalent, necessitating more frequent visits to healthcare professionals as well as more hospitalizations. By 2050, the population of older citizens will have risen to almost 1.5 billion [4]. The rapid development and application of smart and IoT-based technologies have opened a wide range of technical breakthroughs for numerous parts of life. The primary purpose of IoT technologies is to streamline processes in various domains, enhance system efficiency (technology or specialized processes), and ultimately improve living quality.

It is time to find a way to relieve the strain on healthcare systems while still providing high-quality care to at-risk individuals. The Internet of Things (IoT) has been widely touted as a possible answer for easing the strains on healthcare systems [2].

The IoT is transforming healthcare from a traditional hub-based system to a more personalized healthcare system (PHS), and its paradigm symbolizes the vision of the next wave of the ICT revolution, which brings together aspects and technologies from several approaches [19], [20].

IoT smart devices in healthcare offer new and appealing ways to monitor and record patients' data in their homes and workplaces, as well as automatically transmit data to electronic systems. Although IoT integration in healthcare is still in its early stages of development, it is expected that connected medical devices will become ubiquitous and programmable, with the ability to communicate with one another, thereby improving the quality of care and, as a result, the personal health of patients [21].

The Internet of Things has a lot of potential for qualifying and upgrading healthcare services, such as monitoring at any time and in any location. These services collect various bio-signals using various sensors. Electroencephalogram (EEG), electrocardiogram (ECG), the electrical signal of the heart and electromyogram (EMG) were recorded [10]. E-health, assisted living, human-centric sensing, and wellness have all benefited from IoT. This interconnectedness has recently been dubbed e-healthcare, assisted living, human-centric sensing, and wellness [22].

Medical applications such as fitness programs, aged care, remote health monitoring, and chronic illness management can all benefit from IoT technology. These advantages typically include advanced system, service, and device communication that extends beyond machine-to-machine (M2M) scenarios. Traffic congestion, waste management, smart cities, security, smart health, logistics, disaster services, healthcare, trade, and business control are just a few of the applications and services that can benefit from the Internet of Things [13]. Such digital systems can make diagnosing, scheduling appointments, and treating infected patients easier, lowering the risk of viral infection among primary care providers and workers [23].

IoT has provided significant support and has become a key component in the creation of critical cyber-physical systems, and it is being used in a wide range of applications, including healthcare. It has gotten more attention because of its potential to relieve the load on the healthcare system caused by an ageing population, as well as a rise in chronic diseases and worldwide pandemics [14]. With the support of compact, powerful, and intelligent sensing devices and IoT concepts, healthcare availability and accessibility are expanded, and more "personalized" systems are developed alongside high-quality, cost-effective healthcare delivery [5].

Implementing IoT technologies in the healthcare industry provides various advantages, including lower service costs, faster and safer preventive care, greater patient-centered practice, increased sustainability, and improved treatment outcomes. By developing a set of applications and services with the goal of solving many challenges in this area, IoT has proven its efficiency and important role in the development and improvement of healthcare services and their quality [20], [24]. It will allow data to be transmitted between many different types of devices, improve transportation safety, reduce energy consumption, and improve our health [16].

As stipulated by Aghdam et al. [2], [25] physicians and hospital staff will be able to execute their tasks more conveniently and intelligently, thanks to the Internet of Things. Monitoring could, for example, be used to monitor non-critical patients from home rather than in the hospital, lowering the demand for hospital resources like doctors and beds. It could be used to improve rural residents' access to healthcare or to allow elderly people to live independently at home for longer periods of time.

*3.2. What are the Implementation Challenges of IoT in Healthcare Delivery?*

Despite the obvious benefits of e-health platforms, hospitals and outpatient clinics still rely on the traditional medical service model. In medical education, a similar dynamic exists, with traditional methods and approaches remaining the primary means of instructing medical students and residents. The lack of financing, particularly from governments, is another barrier impeding the widespread adoption of digital technology in healthcare [23].

Given the volume of data created, the relevance of timely diagnosis and decision-making, and the importance of quick responses in the event of recognized irregularities, sending all data to the Cloud for analysis may not be acceptable. It is not practicable to upload vast amounts of data to the Cloud for analysis and storage, and it takes time, which might have a detrimental impact on health-related decision-making processes. Current Cloud computing solutions are thought to be incapable of handling the complete amount of data created by IoT [5].

Massive communication within such cyber-physical (IoT) systems poses a wide variety of security challenges. These security malfunctions may disturb the entire applications/systems and lead to lethal consequences. Therefore, trust and security are major prerequisites that may disturb the entire applications/systems and lead to lethal consequences [11].

The rapid growth of IoT technologies results in high demand for raw materials to manufacture various electronic gadgets, which, regrettably, means that some raw resources are currently scarce or will become scarce in the near future. The long-term consequences and sustainability of IoT technologies are unclear and have not been thoroughly examined. Operating IoT devices would require a significant amount of energy, and the electronic industry leaves a variety of negative environmental footprints that must be carefully investigated. Significant advancements in both specific electronic components and user-friendly software solutions are required [26]. Many issues, such as a shortage of cost-effective and accurate smart medical sensors, unstandardized IoT system architectures, heterogeneity of connected wearable devices, multi-dimensionality of data generated, and others, make leveraging the utility of advanced IoT technology in PHS a significant challenge [20].

One of the challenges presented by the emergence of the Internet of Things (IoT) phenomenon is the integration and harmonization of data provided by cyber-physical systems with that already existing and generated by traditional information systems. The biggest drawbacks include the security risk associated with storing a lot of sensitive information in one database, the potential need to periodically recalibrate a person's sensors to ensure accurate monitoring, and the potential for patient disconnections from healthcare services if they were outside of cellular range or their devices ran out of battery [2], [27].

The rise of the Internet of Things (IoT) poses a number of challenges to the healthcare industry, including security and privacy concerns as well as interoperability and standards. There isn't a single IoT architecture that can accommodate all possible IoT-based healthcare applications because there are so many different types of devices and platforms available for deployment [4], [28].

*3.3. Advantages and Disadvantages of IoT Techniques in Healthcare Delivery*

The Internet of Things (IoT) has brought about revolutionary change across many different sectors, including the delivery of healthcare services. Techniques for implementing IoT entail connecting various systems, sensors, and gadgets to the internet. This paves the way for streamlined data transfer and real-time monitoring. The Internet of Things has several possibilities and benefits in the field of healthcare, including the potential to improve patient care, increase operational efficiency, and allow proactive healthcare management. However, in addition to its benefits, there are several drawbacks and difficulties that must be taken into consideration. In Table 1, we examine both the positive and negative aspects of using IoT methods in the delivery of medical care.

Table 1. A table showing the advantages and disadvantages of some IoT technologies

| IoT Technique | Advantages | Disadvantages |
|---|---|---|
| Remote Monitoring | - Enables continuous health monitoring.<br>- Reduces hospital readmissions.<br>- Facilitates early detection of health issues.<br>- Enables personalized and targeted interventions | - Privacy and security concerns<br>- Technical complexities<br>- Data overload<br>- Reliability of data transmission |
| Telemedicine | - Facilitates remote consultations.<br>- Increases access to healthcare services.<br>- Reduces travel time and costs for patients and healthcare | - Limited physical examination capability<br>- Dependence on reliable Internet connectivity<br>- Limited non-verbal reminders during communication |
| Wearable Devices | - Provides real-time health data.<br>- Promotes active patient engagement.<br>- Enables early detection of health issues.<br>- Supports continuous monitoring and feedback compatibility | - Data accuracy and reliability challenges<br>- User acceptance and adoption barriers<br>- Potential for information overload<br>- Technical limitations (e.g. battery life, device |
| AI-based | - Facilitates data analysis for personalized treatment plans | - Ethical considerations (e.g. privacy, bias) |
| Decision Support Systems | - Enhances diagnostic accuracy and efficiency.<br>- Assists in clinical decision-making.<br>- Reduces medical errors and improves patient safety.<br>- Supports evidence-based medicine | - Potential for overreliance on technology<br>- Interpretability and transparency of algorithms<br>- Need for regular updates and maintenance.<br>- Integration challenges with existing healthcare systems |

## 4. Discussion

The digital revolution has had an impact on and reshaped healthcare systems all around the world. It involves shifts in medical service and education's core beliefs and methodologies [20]. Technology is transforming our lives and propelling us into a more technologically advanced world. There is no denying that the Internet of Things growing importance in healthcare has had a significant influence [14]. A large number of significant technological improvements in both hardware and software components are required to develop consistent, safe, effective, timely, flexible, patient-centered, power-efficient and ubiquitous healthcare systems.

Industries are particularly interested in developing and deploying IoT devices as applications and services in the healthcare sector, such as healthcare monitoring [10]. The advancement of the Internet of Things (IoT) has a favorable impact on all aspects of healthcare, and the key advantages of IoT-driven e-health systems are the ability to provide high-quality healthcare to everyone from anywhere [5].

In the field of electronic health (e-health), where existing technologies have been applied to enable speedy access to patient treatment, IoT holds a lot of promise. For reliable patient tracking and registration, healthcare professionals are turning to technological advances. The future components of the healthcare system allow for the creation of mobile applications for people of all standards [29], [30].

The IoT idea has developed into and from several technologies, such as sensors, machine learning, real-time testing, and embedded systems. It deals with the intelligent hospital concept and other fixed- or wireless-based equipment [31]. IoT and e-health are cornerstone technologies that, when combined, completely transform person-to-person, human-to-machine, and machine-to-machine (M2M) communications, changing healthcare in all its forms. E-Health has the potential to alter healthcare delivery by increasing the quality, accountability, and cost-effectiveness of services [19], [21].

Trust, privacy, and security concerns, as well as regulation issues, identification, and semantic interoperability, are pivotal in the widespread adoption of IoT and e-health together. There are still important gaps for future research to address, which relate to the IoT technology itself, the health system, and the users of IoT technology. Future research on IoT technology needs to address how IoT devices can be designed with standardized protocols and interoperability with international and cross-state health systems [17], [21].

The underlying security vulnerabilities and threats of the infrastructure and devices cannot go unaddressed [19]. The scale, complexity, and passive nature of data collection with IoT devices present unique challenges related to security, privacy and personal safety [29]. Another concern is how trustworthy and secure such digital health advances are [23]. By implementing enhancement strategies and approaches, the performance of the current IoT healthcare systems must be enhanced [10]. The successful use of IoT in e-health depends on ensuring efficient resource consumption and processing to improve the operation of healthcare facilities [30]. Even though IoT is technically advanced, the security of the healthcare information and communication technology network is a serious concern [29]. Connection, power, spectrum, bandwidth, and pricing are all common barriers to IoT applications [31].

## 5. Conclusions

For the effective deployment of IoT in e-health, a framework that ensures interoperability between devices for processing and optimal resource use is necessary. Several e-health architectures have been developed, each with its own set of advantages and disadvantages. However, these systems have failed to address several difficulties, particularly scalability. However, implementing IoT-based e-health systems in underdeveloped nations is extremely difficult, although both developing and developed countries share a shared goal of providing health monitoring and evaluation to individuals who do not have access to healthcare [30].

The review discovered, among other things, that the lack of government support for financing IoT initiatives is a barrier to its adoption in healthcare delivery because it requires significant upfront and ongoing capital. However, some medical practitioners still use outdated (manual) methods of providing their services, shunning technological approaches.

We suggest that for the benefit of everyone, philanthropists, corporate entities, and international organizations should assist governments, particularly in underdeveloped countries, in installing and using IoT in healthcare services.

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