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Review Article

The Application of Internet of Things in Healthcare Systems with a Focus on Advantages and Challenges: A Scoping Review

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Abstract
Background: The internet of things (IoT) has become a heterogeneous and exceedingly disseminated structure that can react to the everyday needs of individuals and distinctive organizations. The present study aimed to investigate the application of the IoT in healthcare systems, with a focus on its strengths and challenges.
Methods: Electronic databases, including PubMed, Scopus, SID, and Magiran, were searched for this review study. In addition, a review of the gray literature was undertaken to identify relevant studies in English on the current subject. The titles, abstracts, and full texts were independently screened based on PRISMA guidelines for the scoping literature. General information containing the author(s) name, year of publication, the aim of the study, and specific information, including technologies used in IoT, the medical field, the application of IoT in health, limitations, and strengths, were extracted and analyzed.
Results: Forty-four papers were qualified and contained in the process to 2023. Different studies have mentioned the opportunities for different forms of IoT applications, such as remote consultation, health monitoring and care, medication management, quick diagnosis, and effective treatment. In addition, studies have addressed the challenges in different forms, such as remembering everyday events, fitness, remote rehabilitation, management of chronic diseases, E-Visit, and better management of daily activities.
Conclusion: The challenges and the benefits were classified into nine and ten main groups, respectively. Each of these challenges and benefits, which include smaller and more current elements, can help health policymakers apply the IoT and use its benefits.
Keywords: Internet of things, Telemedicine, Delivery of healthcare, Advantages and challenges, Medical services

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Introduction
Nowadays, the healthcare industry is facing many challenges. The large increase in treatment costs, the unstable regulatory environment, and the change in insurance reimbursement models are among these challenges that can be managed and resolved to a large extent by the efficient use of medical equipment and new technologies such as the internet of things (IoT).

In addition, the IoT has become a heterogeneous and exceedingly disseminated structure that can reply to the everyday needs of individuals and distinctive organizations. Effective centralized administration supervision and public health observation can be realized with the quick advancement of IT-based innovations such as IoT and cloud computing, low-cost health services, and their support (1).

The IoT can be defined as a massive Internet-based network that connects physical and virtual "things" with standardized and interoperable communication protocols (2). From a healthcare perspective, the IoT can be considered any device that can collect data related to people's health using computing devices, mobile phones, smart bands and wearables, digital medicines, devices implantable, surgical devices, or other portable collection devices (3).

Based on previous forecasts and analyses, the IoT is one of the most popular technological trends in healthcare, and its application in medicine is becoming more widespread over time. Some of these applications and benefits include reducing the waiting time in emergency room queues, tracking patients, medical staff, and equipment, improving drug supply and demand management, ensuring the availability of necessary equipment, remote health monitoring, and helping diagnoses abnormalities in the early stages, rapid identification of symptoms and clinical diagnoses, provision of early intervention and improvement of adherence to prescriptions, chronic disease management, and elderly care (4,5).

Kulkarni and Sathe surveyed the applications of IoT within the healthcare sector to offer the leading benefit at sensible costs. They clarified how IoT acts and how it is utilized in conjunction with remote and detecting frameworks to execute the needed healthcare applications (6).

In addition, the results of studies have shown that the healthcare system can be significantly improved using IoT devices. The concepts of e-health, service quality, and patient safety can be supported by advanced monitoring systems, and the prediction of life-threatening situations can be effectively made with better treatment of patients, such as timely treatment decisions. Further, the use of IoT can help effectively monitor and control epidemic diseases such as COVID-19 (7) and plays an important role in increasing the accuracy, reliability, and efficiency of electronic devices in the healthcare industry (8).

Lately, the concept of the Internet of Health Things, or the Internet of Medical Things (9), has risen as a modern concept for a coordinated and proactive healthcare framework based on IoT to supply and handle information in real-time. The Internet of Health Things could be a holder for all the past concepts. It has other modern highlights such as mindfulness, shrewd restorative gadgets, robots, and telehealth, as well as the advancement of restorative instruction utilizing virtual reality methods, holographic tangible communication, and 3D imaging for a way better conclusion of the illness (10).

Due to the vastness of the healthcare sector, it is difficult and expensive to provide healthcare services to patients. Today, the IoT, as one of the most commonly deployed innovations in e-health, has centralized healthcare services from health centers to peripheral locations such as homes and workplaces (11).

While IoT e-health promises to improve integrated communications in which clinics and hospitals can collaborate and coordinate with each other to improve services provided to patients, this technology also faces challenges that must be addressed. It overcame them before becoming mainstream (12). Challenges such as security and privacy, interoperability, and integration of technology issues in the IoT have been investigated in a number of papers (13-18).

However, to the best of our knowledge, no study has evaluated the challenges, advantages, and disadvantages of the IoT in healthcare systems. Accordingly, the present study sought to investigate the application of the IoT in healthcare systems, with a focus on its strengths and challenges.

Materials and Methods

Study Design

The present study adopted Arksey and O'Malley's framework to perform a scoping review, which comprises 5 main stages and one selective stage as follows:

1. Identifying the research question
2. Identifying relevant studies
3. Selecting the studies
4. Charting the data
5. Collecting, summarizing, and reporting the results (19).

The questions examined in this review study were as follows:

1. What is the purpose of studies on the use of IoT in healthcare institutions?
2. Which medical fields use IoT?
3. What technologies are utilized in IoT?
4. What are the principal strengths and challenges of IoT in healthcare systems?

Information Sources

We conducted a search in electronic databases, including PubMed, Scopus, SID, and Magiran, for published articles until July 25, 2023. No restriction related to the date of publication was applied. We searched the Google search engine to identify all the related articles. A combination of medical subject headings (MeSH) and terms related to IoT, healthcare systems, strengths, and challenges was applied in the search strategy. The full search strategy is provided in Table 1.

Selection Criteria

Based on the following inclusion and exclusion criteria,

Table 1. Search Strategy in Scientific Databases

Search Strategy	
Time limitation	Until July 25, 2023
Language limitation	English and Persian
Database	Magiran, SID, PubMed, and Scopus
#1	"Internet of Things" OR "IoT" OR "Internet of Medical Things" OR "IOMT"
#2	"Challenge*" OR "Limitation*"
#3	"Opportunity*" OR "Strengths" OR "Benefit*"
#4	IRAN
Search	#1 AND #2 AND #3 AND #4

a decision was made regarding including studies in this scoping review:

The inclusion criteria were original research papers, studies published in the English language, studies related to the aim of the study, such as IoT for healthcare, studies published until 2023, and studies performed by Iranian researchers.

The exclusion criteria were reviews, meta-analyses, dissertation theses, reports, conference abstracts, letters to the editor, commentaries, and systematic review protocols, studies published in languages other than English, unavailability of full text for data extraction, and studies unrelated to the aim of the study.

Study Selection

All studies identified were imported into EndNote X20 citation management software (Thomson Reuters, Toronto, Ontario, Canada). Through this software, four authors (S. P., A. S., E. E., and R. H.) independently screened the titles and abstracts of all studies identified by the search criteria. Full texts of the remaining relevant studies were obtained, and two authors read the full-text papers and made a final selection of relevant studies. Any disagreements were resolved by discussion and consensus between the authors and then by another person on the study team. The full texts of reviewed articles that did not meet the inclusion criteria were removed, and reasons for exclusion were noted accordingly. In addition, the final decision for the selection of relevant studies was made by reading the full-text papers.

Data Extraction

A piloted data collection form in Excel (Microsoft, 2019) was used to extract data from the included studies. The four reviewers (SP, AS, EE, and RH) performed data extraction independently. Any disagreement among the authors was resolved by discussion among all authors.

This form included the following characteristics from each study, when available:

- General information: Author's name, year of publication, and aim of the study
- Specific information: Technologies used in IoT, medical field, application of IoT in health, limitations, and strengths.

Data Synthesis and Analysis

Based on the study variables, the descriptive analysis, including frequency and percentage parameters, was calculated and presented in the form of graphs and tables. In the result section, a narrative synthesis is applied to describe and compare the paper's results. Meta-analysis was not the aim of this scoping review due to the diversity of outcomes and results.

Results

Search Output

A total of 2195 potentially relevant articles were initially identified from the three databases; overall, 196 articles were removed due to duplication, and the remaining 1999 studies were screened. Then, 1866 articles were excluded due to low relevance based on the title and abstract, and 133 full-text articles were screened. The characteristics of the excluded studies are shown in the PRISMA diagram. After applying all eligibility criteria, 44 articles were included in the review (Figure 1).

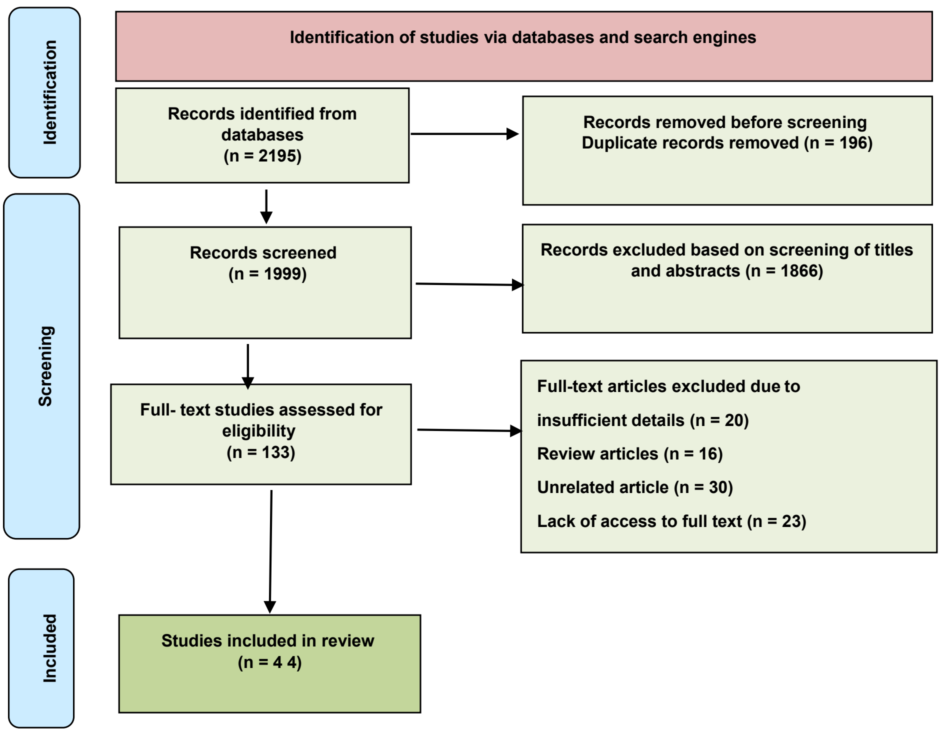

Figure 1. PRISMA Flow Diagram of Scoping Literature Search and Selections. *Note*. PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Characteristics of the Included Studies

The characteristics of the 44 studies are presented in Supplementary file 1. The oldest and newest studies were published in 2017 and 2023, respectively. IoT applications in most studies were health monitoring and care and tele-visits. Descriptive and practical studies were the most and least repeated types, respectively. Most studies focused on cardiovascular diseases and COVID-19.

Note. IoT: Internet of things; COVID-19: Coronavirus disease 19.

Overall, 44 studies were included in this review. The challenges and benefits extracted from these 44 papers were analyzed based on article reference number, author's name, year, aim of study, study type, technologies used in IoT, medical field, application of IoT in health, limitation, strengths, and results.

As shown in Figure 2, most studies (29.54%, 13 articles) were published in 2021, and the remaining 6.81% were published in 2023.

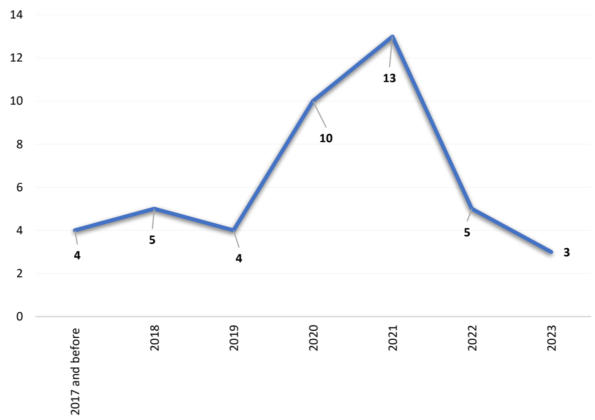

Figure 2. Frequency of Studies Based on Publication Year

Different studies have mentioned the challenges and opportunities of different forms of IoT applications, such as remote consultation, health monitoring and care, medication management, quick diagnosis and effective treatment, rapid identification of patients, and saving time, cost, and energy for patients.

Moreover, studies have addressed the challenges and opportunities in different forms of the purpose of IoT application in healthcare, such as remembering everyday events, fitness, and remote rehabilitation, managing chronic diseases, creating connections between different medical sources, providing smart services, data integrity in the health network, and E-visit, and better managing daily activities (Figure 3).

Numerous challenges and opportunities related to the use of personalized mobile technology applications were addressed in this study, and a comprehensive classification of them was prepared accordingly. The most important benefits and challenges in the studies are presented in Tables 2 and 3, respectively. As depicted in Figure 3 and Table 2, preventing possible life risks and diseases and taking timely actions in this regard, providing better medical services, reducing medical and hospital costs, and monitoring and providing remote services are among the most mentioned advantages. On the other hand, faster identification of diseases, awareness and collection of real-time data about patients, preservation of patient information and privacy, and management of information, resources, and hospital equipment received less attention.

The results indicated that 67.10% of the advantages were preventing possible life risks and diseases and taking timely actions in this regard (n = 13, 29.54%), reducing medical and hospital costs (n = 13, 29.54%), monitoring and providing remote services (n = 13,

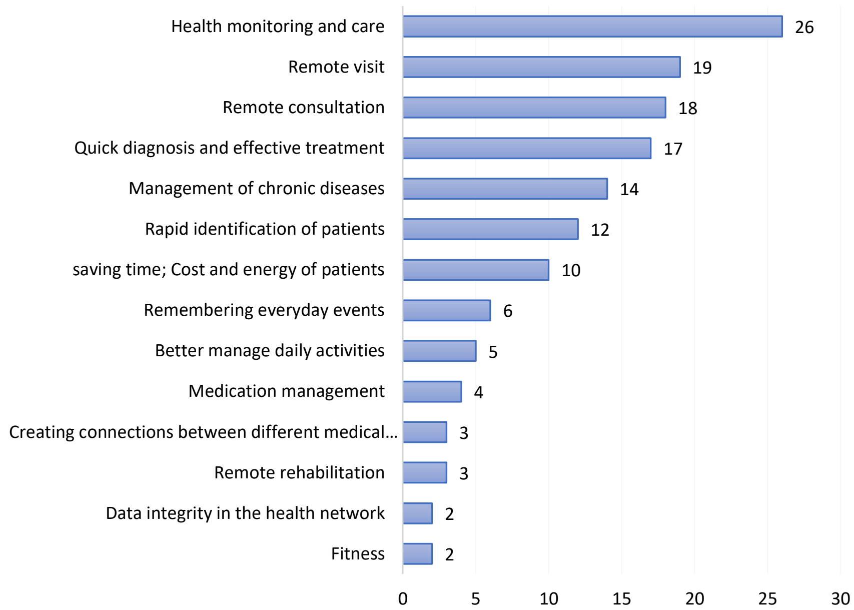

Figure 3. Frequency of Repetition of IoT Application Cases in Studies. *Note*. IoT: Internet of things

Table 2. Identified Advantages of the IoT

Advantages of the IoT	References	Repetition Frequency (%)
Preventing possible life risks and diseases and taking timely actions in this regard	(20,23,29-32,34,35,43,44,49,51,58)	13 (29.54)
Providing better medical services	(21,22,26,31,33,37,41,50,51,57,61,62)	12 (27.27)
Identifying diseases faster	(20,55,56)	3 (6.81)
Reducing medical and hospital costs	(21-23,32,35,40,42,46,48,49,53,54,59)	13 (29.54)
Reducing medical errors and helping in making a better diagnosis	(21,24,31,42,50,59,60)	7 (15.90)
Reducing the number of visits to hospitals and reducing the workload of medical personnel	(25,40,42,45,54)	5 (11.36)
Monitoring and providing remote services	(12,21,22,25,27,31,34-36,52-55)	13 (29.54)
Being aware and collecting real-time data about patients	(22,28,29,40,58)	5 (11.36)
Preserving patient information and privacy	(45-47,59)	4 (9.09)
Managing information, resources, and hospital equipment	(55)	1 (2.27)

Note. IoT: Internet of things.

Table 3. Identified Challenges of the IoT

Challenges of the IoT	References	Repetition Frequency (%)
The challenge of maintaining the security of patients' personal information and their authentication and hacking	(12,24,27,31,34,37,41,46,48,52,59)	11 (25)
The limitations of information storage, low processing power, and high energy consumption	(12,25,32,34,36,43,47,58,60)	9 (20.45)
Lack of access to suitable internet speed and bandwidth for this technology and security and communication problems	(26,38-40,42,47,53,57,58,60-62)	11 (25)
The need for a lot of time to develop this technology	(28)	1 (2.27)
The high price of the equipment of this technology and the difficulty of its implementation	(30,12,33,51)	4 (9.09)
Concerns and legal problems with using this technology	(12,33,50,55,59)	5 (11.36)
Endangerment of people's lives in case of any inefficiency or failure of equipment and electronic devices	(34,35,39)	3 (6.81)
The newness of this technology and the lack of studies in this regard, and the problems and errors while working with it	(37,44,48,50,54)	5 (11.36)
Lack of infrastructure and facilities for this technology	(55,57,61)	3 (6.81)

Note. IoT: Internet of things.

29.54%), and providing better medical services (n = 12, 27.27%). Managing information, resources, and hospital equipment (n = 1, 2.27%), preserving patient information and privacy (n = 4, 9.09%), identifying diseases faster (n = 3, 6.81%), reducing the number of visits to hospitals and the workload of medical personnel (n = 5, 11.36%), being aware and collecting real-time data about patients (n = 5, 11.36%), and reducing medical errors and helping to make a better diagnosis (n = 7, 15.90%) were less mentioned advantages.

As shown in Figure 3 and Table 3, the challenges of maintaining the security of patients' personal information and their authentication and hacking, the limitation of information storage, low processing power, high energy consumption, lack of access to suitable internet speed and bandwidth for this technology, and security and communication problems are among the most mentioned advantages, while the need for a lot of time to develop this technology and the lack of infrastructure and facilities for this technology have received less attention.

With regard to the challenges, the results indicated that 50% were related to the challenge of maintaining the security of patients' personal information and their authentication and hacking (n = 11, 25%), the lack of access to suitable internet speed and bandwidth for this technology, and security and communication problems (n = 11, 25%). The moderate challenges were the high price of this technology equipment and the difficulty of its implementation (n = 4, 9.09%), concerns and legal problems in using this technology (n = 5, 11.36%), the newness of this technology and the lack of studies in this regard, as well as the problems and errors while working with it (N = 5, 11.36%). The need for a lot of time to develop this technology (n = 1, 2.27%), lack of infrastructure and facilities for this technology (n = 3, 6.81%), endangerment of people's lives in case of any inefficiency, and failure of equipment and electronic devices (n = 3, 6.81%) were less mentioned advantages.

Given the importance of this issue, based on the findings of our study, most IoT applications were related to 62 chronic conditions, such as COVID-19 (n = 10), cardiovascular diseases (n = 8), Alzheimer's disease (n = 4), general health (n = 12), and chronic conditions (n = 6), totally, 90.9% (Table 4).

Table 4. Frequency of the Study Based on the Disease or Condition

Disease or Condition	Count of Study	Percent
General health	12	27.27
Chronic conditions	6	13.63
Alzheimer's disease	4	9.10
COVID-19	10	22.72
Cardiovascular diseases	8	18.18
Hybrid or other (diabetes, surgery, tooth, skin, fitness, orthopedics, and the like)	4	9.10

Discussion

The IoT has become a miscellaneous and extremely distributed architecture, capable of meeting the daily needs of distinct individuals and organizations. This review was conducted to investigate the challenges and advantages of applying IoT to healthcare systems. In this research, 44 studies were found with regard to the IoT. Many challenges and opportunities associated with personalized mobile technology applications have been discussed in this study, and a comprehensive classification of them has been prepared.

The identified challenges and opportunities related to the use of IoT were classified into 9 and 10 groups, respectively.

It is shown that most IoT technologies were developed and discussed in 2021 (n = 13) by Iranian researchers. The challenges in maintaining the confidentiality of patients personal information as well as authentication and hacking, limited information storage, low processing power, high energy consumption, and lack of fast internet access and high bandwidth are suitable for this technology, and security and communication issues are among the most mentioned advantages. However, the need for a lot of time to develop this technology and the lack of infrastructure and equipment for this technology received little attention.

An increase in the size of population leads to several kinds of diseases, especially chronic diseases, which are costly for governments (63). Mortality numbers and chronic disease rates are increasing faster in developing countries than in developed countries (63). Health-related problem-solving increases the care level for chronic disease, improves clinical outcomes, and decreases disease burden costs (64). Patients' desire for self-management and the development of health technologies and programs heavily depend on patient control (65). Furthermore, many people want to spend time in their home environment and take advantage of healthcare services (66). Generally, the adoption of IoT applications by medical end-users is extremely low. A medical professional faces significant challenges in successfully implementing IoT for healthcare service delivery. Numerous studies have provided important insights into the adoption of IoT in healthcare (67).

In the current study, the benefits and advantages of IoT are categorized into ten main groups, including preventing possible life risks and diseases and taking timely actions in this regard, providing better medical services, identifying diseases faster, reducing medical and hospital costs, reducing medical errors, reducing the number of visits, monitoring and providing remote services, being aware and collecting real-time data about patients, preserving patient information and privacy, and managing information, resources, and hospital equipment.

Current IoT health devices include heart rate monitors, electrocardiographs, blood glucose monitors, pulse oximeters, and blood pressure monitors. In the near future, they are expected to be supplemented with micro- and nano-chemical sensors that will enable the provision of continuous medical diagnostics. These miniature smart sensors will be able to detect additional chemical signatures (e.g., in breath and sweat), which may lead to medical monitoring, such as diabetics, other metabolic diseases, skin diseases, and the pharmacokinetics of drugs (68,69).

IoT devices can monitor patients' vital signs, such as heart rate and blood pressure. In addition, they can track medication adherence and provide real-time alerts to caregivers in case of a change in a patient's condition. The IoT can also help hospitals manage their assets more effectively (70). Nausheen et al considered continuous health monitoring, which makes hospitals smarter, helps keep track of patients, makes insurance claims transparent, makes cities healthier, and helps in medical research, as the benefits of the IoT application (71).

Understanding the challenges in this area helps project developers and managers create a reliable evaluation framework for reviewing healthcare systems and solutions, preventing future problems. Moreover, this knowledge will help policymakers at the national and international levels achieve more (72). Advantage and challenge concerns with IoT can adversely affect patients' and healthcare providers' trust and acceptance and can pose risks to the success of IoT applications and their widespread use more generally. It is necessary to effectively use information technology for health purposes through the establishment of effective and efficient policies, regulations, and policies.

Maintaining the security of patients' personal information and their authentication and hacking was the most repeated challenge in this study. Further, the increasing use of IoT devices has made IoT networks vulnerable to various security attacks. Efficient security and privacy protocols are urgently needed in IoT networks to ensure confidentiality, authentication, access control, integrity, and the like (73).

In the current study, the barriers to IoT were categorized into nine categories. They were security maintenance, limitation of information storage, lack of access to suitable internet speed, lots of time to develop technology, high cost, legal problems, endangerment of people's lives, lack of studies in this regard, and lack of infrastructure and facilities. In their research, Mayer et al identified that the protection of data and privacy of users is one of the key challenges in the IoT. They indicated that a lack of confidence in privacy will result in decreased adoption among users, and therefore, confidence in privacy is one of the driving factors in the success of the IoT. In their opinion, the IoT can be categorized into eight topics, including communication to enable information exchange between devices, sensors for capturing and representing the physical world in the digital world, actuators to perform actions in the physical world triggered in the digital world, and storage for data collection from sensors. The other topics were identification and tracking systems, devices for interaction with humans in the physical world, processing to provide data mining and services, localization and tracking for physical world location determination and tracking, and identification to provide unique physical object identification in the digital world (74). Furthermore, they categorized the challenges in IoT into six main groups, namely, integrity, authenticity, confidentiality, privacy, availability, and regulation.

Kumar and Patel discussed privacy concerns that need to be addressed, namely, privacy in devices, privacy during communication, privacy in storage, and privacy at processing. They considered confidentiality, integrity, availability, non-repudiation, accountability, reliability, privacy, and physical security as challenges in IoT applications (75).

Study Limitations

The researchers' lack of access to Scopus and PubMed databases over different periods of time caused the search to be repeated several times based on the defined strategy. However, the search was repeated until reaching data saturation. Therefore, researchers can claim that a search has been conducted using a scoping review method and no study has been ignored at all.

Conclusion

The IoT is rapidly coming closer. Identifying its challenges and benefits can have a great impact on its use. The application of the IoT in medicine, considering the complexity and extent of medical services, can be highly effective for doctors, health service providers, and patients. Moreover, by considering the potential challenges in this field, developers of IoT-related systems can overcome many obstacles. Given that the benefits of this technology are not hidden from anyone, in this research, the researchers classified the challenges and benefits into nine and ten main groups, respectively. Considering each of these challenges and benefits, which include smaller and more current elements, can help health policymakers apply the IoT and use its benefits. In the IoT space, there are often many different alternative technical solutions for healthcare applications, implying that real-world projects need to analyze all possible primary solutions to determine optimal solutions, taking into account the corresponding specific constraints and priorities of applications. Therefore, it is important to have a structured system engineering approach to guide the respective decision-making processes to develop the IoT healthcare ecosystem.

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Authors' Contribution

Conceptualization: Shahrbanoo Pahlevanynejad, Azam Sabahi, Seyyed Reza Hosseini
Data curation: Shahrbanoo Pahlevanynejad, Azam Sabahi, Seyyed Reza Hosseini, Elham Salmani, Neda Radmehrnia, Mahsa Zamini, Erfan Esmaeeli.
Methodology: Shahrbanoo Pahlevanynejad, Azam Sabahi.
Supervision: Shahrbanoo Pahlevanynejad, Azam Sabahi.
Writing–original draft: Shahrbanoo Pahlevanynejad, Azam Sabahi.
Writing–review & editing: Shahrbanoo Pahlevanynejad, Azam Sabahi, Seyyed Reza Hosseini, Elham Salmani, Neda Radmehrnia, Mahsa Zamini, Erfan Esmaeeli.

Competing Interests

The authors have no conflict of interests associated with the material presented in this paper.

Ethical Approval

Not applicable.

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Supplementary Files

Supplementary file 1 contains Table S1.

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