Internet of Things (IoT) Saudi Arabia Healthcare Systems: State-Of-The-Art, Future Opportunities and Open Challenges

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Abstract

Background: Internet of Things (IoT)-based health care applications are designed to explore and exploit the latest communication technologies in a manner that connects health care providers and patients by way of added-value services such as the remote monitoring of patient health and the availability of data analytics applications for clinicians and patients alike. This study aimed to provide a qualitative analysis of the enabling technologies, applications, benefits, challenges, future opportunities, and prospects for IoT-based health care applications that have been introduced to date in collaboration with some of the hospitals and medical cities in Saudi Arabia.

Method: A qualitative research design was used. Open-ended interviews were conducted with 10 informants, including information technology (IT) executives, IT directors, IT managers, and health informatics specialists, who were selected due to their knowledge of the health care systems in the medical cities of Saudi Arabia.

Results: State-of-the-art IoT technologies are not yet applied in the medical cities of Riyadh, Saudi Arabia. The results of the study show the most challenges with IoT technologies that affect patient's privacy and security and how to have this technology be safe, reliable, and accessible. Moreover, the benefits of IoT lie in its use for patients, which can increase the quality of care and services, increase the patient satisfaction and patient experience, and reduce the cost of time and amount of effort required for providing the best care for patients. Furthermore, standardization of IoT facilitates communications and accessibility of care between patients and health care providers.

Conclusion: There is a strong need to an infrastructure of health information systems in most of Saudi medical cities that fit with IoT. Furthermore, the attainment of higher numbers of staff with more experience in this field is warranted. However, the present research highlights that the promotion of the use of IoT in medical cities should be more focused on training the users and pushing them to increase adoption of IoT. The initiation of real projects that apply IoT in health care should also be promoted. These findings may also be useful for health care professionals when implementing future IoT health care services in Saudi medical cities for superior patient management.

Key words: Internet of Things, IoT, health care systems, health care technologies, Saudi Arabia health care systems.

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1. INTRODUCTION

The Internet of Things (IoT) represents an emerging and trending technology in the information revolution that has occurred since the birth of the Internet. IoT is a massive, intelligent network that connects billions of objects, which communicate via the Internet with the aim of exchanging information and integrating devices with one another via standard protocols. One of the key goals of IoT is the concept of "smartly" identifying, locating, tracking, monitoring, and managing things. It is an extended network based on the Internet that allows for connections to be made between humans as well as between objects. The development of IoT systems is a very complex technological innovation that involves the establishment of a specific domain to deploy the stages of an application development strategy. These applications support several services that integrate with the service provider and the business processes of different end-users based on public information services and across various platforms. Often, different IoT applications have common features including sharing information locations, information-gathering, and sensing the environment that collects all physical and chemical behavioral data of the environment. These applications can be used to detect and track natural disasters such as volcanoes and earthquakes as well as in remote medical monitoring and controlling. Furthermore, they can analyze data gathered from a patient via wearable devices and provide information on patterns of patient behavior to inform physician health advice. In addition, IoT networking should have the capability to interoperate with other networks' layers to support services and establish a secure channel between applications and platforms to transform data [1, 2].

This research will focus specifically on the status of health care IoT applications in Saudi Arabia. In principle, IoT-based health care applications are designed to explore and exploit the latest communication technologies to establish a bridge between health care providers and patients by way of added-value services such as the remote monitoring of patient health and the availability of data analytics applications for both clinicians and patients to use. Therefore, this research aims to provide a qualitative analysis of the existing technologies, applications, benefits, challenges, future opportunities and prospects for IoT-based health care applications that have been implemented in collaboration with some of the hospitals and medical cities in Saudi Arabia. Dimiter et al. [3] previously described many technologies that can reduce the costs of the prevention and management of chronic diseases. These technologies include devices that monitor continuously the indicators of health, devices to administer therapies automatically, and devices

to track the health data of a patient in real time as the person self-administers therapy. With the widespread and ongoing increase in access to the Internet and smart devices, many patients are beginning to use mobile applications to monitor their health behaviors. These mobile applications and devices can be continuously integrated with telemedicine via the medical IoT (mIoT) system. The mIoT incorporates most trends of digital transformation in the health care sector. Moreover, it allows for new business models to emerge that enable us to implement changes in the processes of medical diagnosis and treatment as well as reimbursement and that improve the productivity of medical professionals and enhance the experiences of a customer in health care. It is expected that the integration of devices and mobile applications will drive the digital revolution in health care and raise the interpretations of relevancy data in analytics, leading to a reduction in the amount of time required for decision-making. Separately, Mostafa et al. [4] reviewed the applications of wearable devices based on medical IoT. The expected demand for personalized health monitoring and preventive medicine has increased due to the rising number of elderly people worldwide. IoT technologies can minimize the overall costs of health care monitoring via the implementation of wearable devices. However, the integration of wearable devices and mobile applications with telemedicine leads to applying the mIoT.

Mostafa et al. [4] defined the architecture design of mIoT to include the hardware, the software that connects with the wearable devices, the sensors, the smartphones, the medical applications, and the medical station analyzer devices used for diagnosis and data storage. Moreover, wearables devices were developed to improve the health monitoring systems in the long-term and incorporated a wide range of health monitoring indicators such vital signs and fitness level. At the end of the investigation, the wearable devices were being used in a large span of health care observations and the sensors were deemed the most important element for collecting data. Through recent years, with the ongoing improvement in IoT technologies, advancements in sensors will bring the adoption of additional indicators closer to reality. Konstantinos et al. [5] described new services that can be integrated with an IoT framework in health care to support the efficiency of medical treatment and automated supervision of medicine. Related to the context of awareness, the framework plays a critical role in realizing the vision of IoT and providing contextual information to help the system function more efficiently. However, with the uniqueness of certain characteristics in the health care context, it is important to specifically define the framework of context awareness for IoT applications in health care. To this end, Konstantinos et

al. [5] identified the context of health care applications and the procedures of context awareness. Moreover, they presented the architecture of sensors that connect to measure the biometrics of data with networks of sensory environment, many IoTs middleware that establishes in a different geographical area and, discussed the challenges of realization in the vision of IoT. In practice, IoT applications have been introduced in only a few hospitals in some countries that demonstrate a rapidly improving quality of health care as compared with different sectors. The health care IoT-based applications are enhancing remote monitoring, remote device configuration, and data analytics applications and supporting laws and regulations–compliant data security. However, health care providers must also take advantage of IoT offerings in order to improve the quality of care they provide and promote patient satisfaction.

2. METHODS

2.1 Research Design and Data collection

A qualitative research design was used. Open-ended interviews were conducted with 10 informants, composed of information technology (IT) executives, IT directors, IT managers, and health informatics specialists who were selected for their knowledge of health care systems in the medical cities of Saudi Arabia. This design was used to collect information from experts about IoT-related technologies and suggestions for promoting a deeper understanding of IoT in the medical domain.

2.2 Research Settings

The research was conducted with the IT departments that were mainly concerned with systems in the health care field and who were working in medical cities in Riyadh, Saudi Arabia including King Abdelaziz Medical City [KAMC], King Fahad Medical City [KFMC], Prince Sultan Military Medical City [PSMMC], King Abdullah bin Abdelaziz University Hospital [KAAUH], King Faisal Specialist Hospital and Research Center [KFSHRC], King Abdelaziz University Hospital [KAUH], and Dr. Suleiman Al-Habib Medical Group. This study was developed in the departments of Information Technology and Health Informatics that were mainly interested in the management and development of health care systems in terms of promoting and providing a better quality of services to patients.

2.3 Data Analysis

A qualitative analysis was performed using the grounded theory method. The grounded theory method of analysis aims to determine a set of procedures based on coding the existing processes and sampling existing relevant theories [7]. After gathering data using interviews and through the data processing and analysis, proportion analytics were used to explore the impact of significant results on the target users.

This was done through the following steps in the data analysis process:

1. By conducting and recording the interviews with the candidate experts. During the interview process, notes were taken enclosing the aspects of the interaction that the recording did not pick up.
2. By transcribing/writing the extracted information into word processing files including judgments about what level[s] of detail to choose as well as key notes about data interpretation and data representation, indicating the first step in analyzing data.
3. By coding the data into themes using a simple approach to facilitate the identification of similar words or phrases mentioned by the interviewees. As soon as these phrases were found, these were placed into categories.
4. The themes and categories were then generalizing in accordance to the phenomena in question and the context of the current study was explained to them [8].

3. RESULTS

Ten participants met the inclusion criteria of the study while, all of them agreed to participate. The characteristics of the 10 participants included are shown in Table 1. The results of analysis process were categorized into eight main themes, as follows 1) Medical cities working on IoT technologies, 2) Impact of IoT technologies, 3) Expectations of IoT support use, 4) Promotion of the use of IoT technologies, 5) Benefits of IoT technologies, 6) Challenges of IoT implementation, 7) The growth of patient satisfaction, and 8) Risks present after applying IoT in medical cities.

Participant	Role	Current institution/employer	Experience (years)
P1	Director of Information Technology	King Abdullah bin Abdelaziz University Hospital	10
P2	Enterprise Architecture Department Manager	King Fahad Medical City	13
P3	Director of IT Business Services	Dr. Suleiman Al - Habib Medical Group	+6
P4	Deputy Chief Information Officer	King Faisal Specialist Hospital and Research Center	24
P5	Senior Programmer Analyst	King Abdelaziz Medical City NGHA	5
P6	Health Informatics	King Abdelaziz University Hospital	17
P7	Health informatics	Lean Company	5
P8	IT Project manager	King Abdelaziz University Hospital -Dental Hospital KSU	4
P9	Medical Informatics	Prince Sultan Military Medical City	+7
P10	Chief Information Officer	King Abdelaziz Medical City NGHA	22

Table 1: Study participant characteristics.

3.1 Medical cities working on IoT technologies: All participants agreed in terms of the medical cities working on IoT that many of them have no idea about best practices. For example:

"This is a new trend and we not sure of usages in other medical cities" (P4).

"I have no idea, but in Jubal, they are working on it, as well as in Newm" (P9).

3.2 Impact of IoT technologies: Six participants expressed about the impact that IoT technologies will have in a particular health care setting, improving the quality of health care in many dimensions so as to provide a lot of information related to patient behavior and health along with the effects of medication and completed treatment plans. One participant suggested the following:

"Definitely, it will enhance the patient care and the quality of treatment as the medical decision will be based on the evidence and the collection of data from multiple tests or exams as well as the individual patient's lifestyle" (P9).

Four participants discussed aspects regarding the impact of IoT technology on patient lifestyle and patient's treatment experience. One participant noted the following:

" Because of the many medical specialties and the variety of patient journeys, the stages are complex and long and therefore IOT can play a major role in the patient's treatment experience" (P3).

Three participants talked about the impact of IoT on improving patient safety and in disease prevention, due to its ability to access and incorporate medical files containing patient data, history of illness, chief complaints, medicines used, and radiation protocols so that duplication and repeated information can be avoided. Three participants also suggested IoT would improve health care in general to be faster and more accessible and available, as the following participant explained:

"They really value IoT and they know that IoT could enable a lot of solutions" (P10).
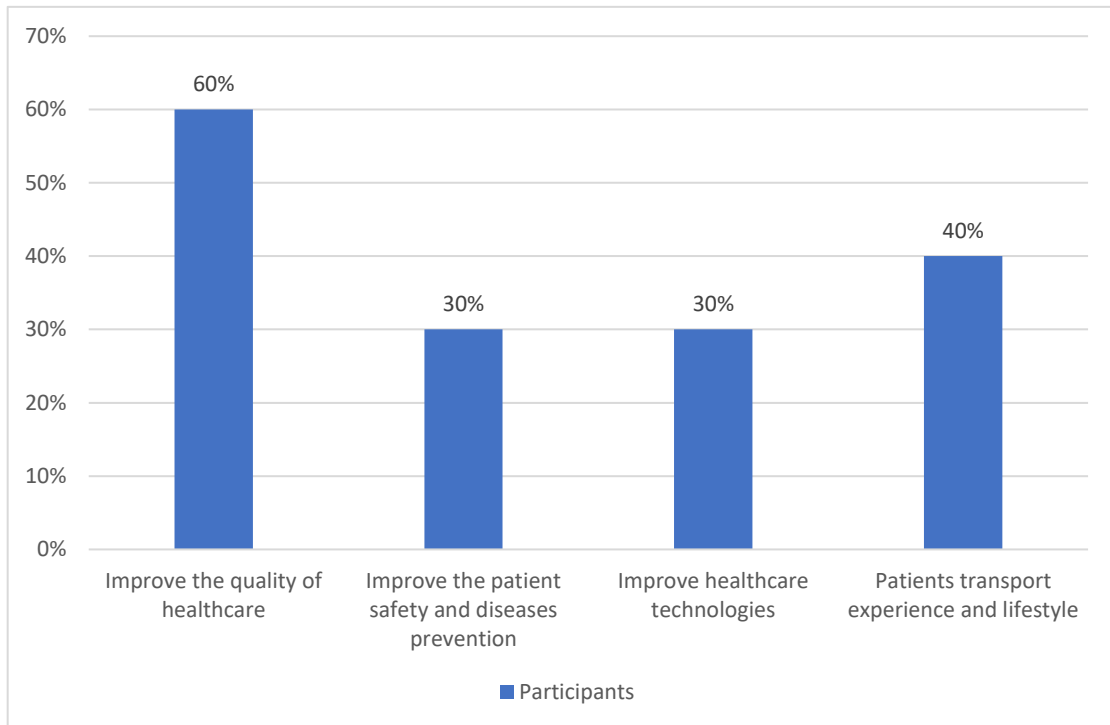

Figure 1: Impact of IoT in Saudi health care systems.

3.3 Expectations of IoT support use: Eight participants highlighted positive aspects of IoT in health care. It represents an effective option, a convenient method, free of problems solutions and

a method that facilitates procedures. Two participants suggested that the effects and success of IoT use depend on the age and knowledge of users.

3.4 Promotion of the use of IoT technology*:* Four participants indicated that training the users and pushing them to increase adoption will help with the promotion of IoT technology. Three participants suggested involving IoT technologies in real projects applying IoT in the health care sector could assist; for example:

"The medical cities should start real projects that apply IoT in Saudi Arabia; this will help us to smartly benefit from the technology, reduce the cost, and increase the satisfaction of patients"

(P2).

Two participants stressed that, for promoting use of IoT, an architecture to situate the IoT-based ubiquitous applications is needed. Moreover, an infrastructure needs to be ready for health information systems use, as the following participant explained:

"We are talking about the future. The big problem is that, unfortunately, medical cities without exaggeration do not have an effective health information system setup established" (P3).

The rest of the participants highlighted and discussed the features of IoT in terms of promoting decision-making and planning treatment customization.
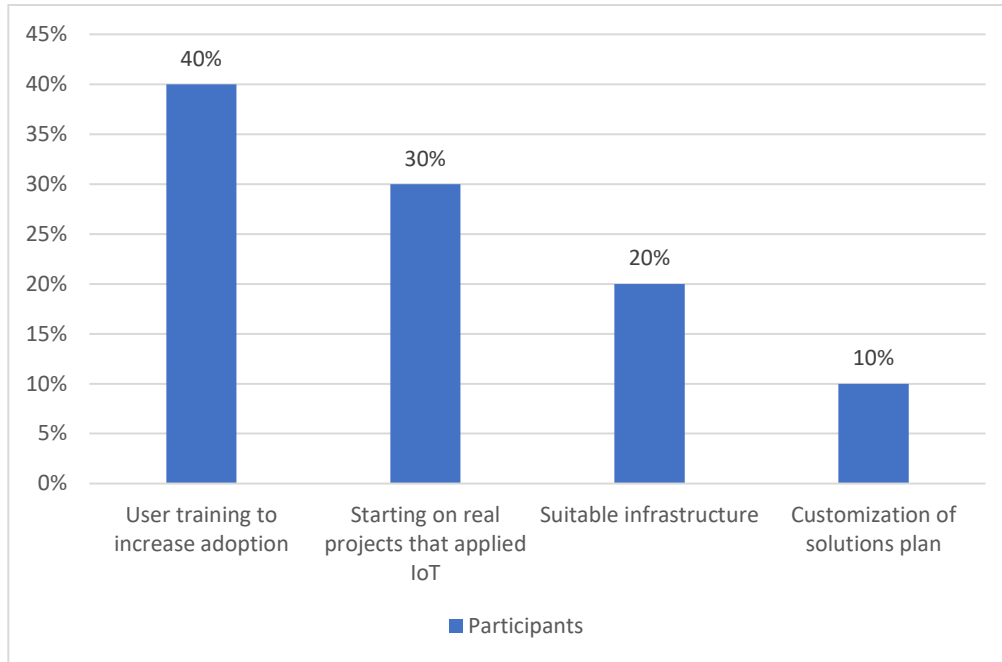
Figure 2: Promotion of the use of IoT in Saudi medical cities.

3.5 Benefits of IoT technologies: Seven participants believed the benefits of IoT lie in its use for patients, which can increase the quality of care and services, as the following participant explained:

"With the increasing population, the application of IoT technologies will raise awareness among patients to get more engaged in their treatment and increase patient experience as well as provide long-term services to patients who cannot reach the hospital" (P6).

Five participants discussed the benefits of IoT use in terms of increasing patient satisfaction and patient experience along with reducing the cost of time and amount of effort required for providing the best care for patients. Three participants suggested IoT provides a lot of predictive analytics for many services that will assist in providing better care for patients. Three participants theorized that IoT facilitates communications for and the standardization of the accessibility of care.
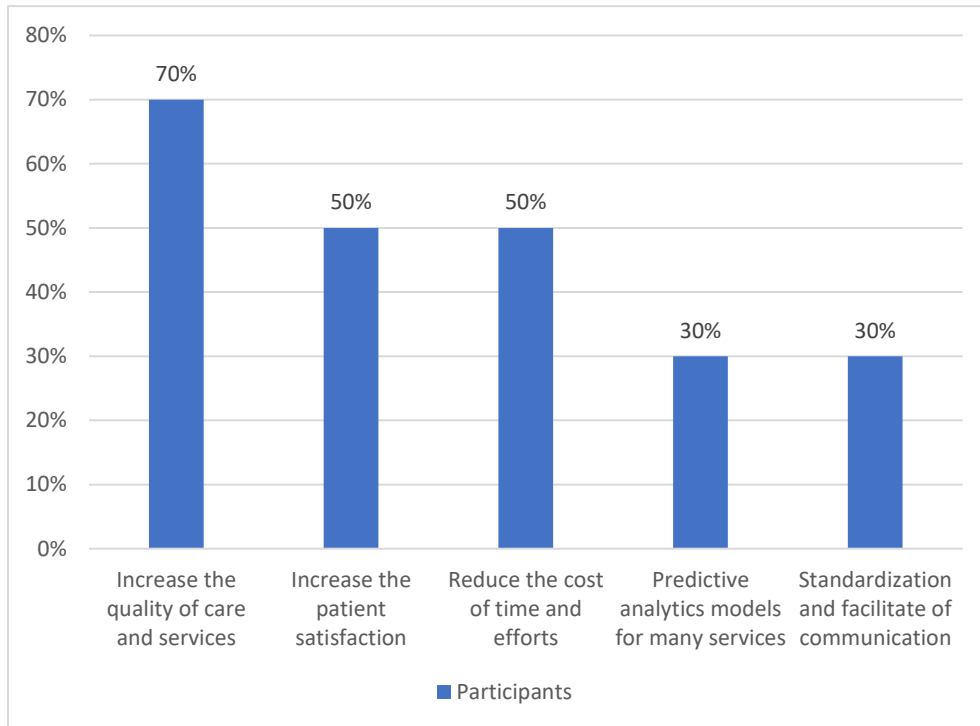
Figure 3: Benefits of IoT technologies for patients.

Two participants believed IoT use will benefit service providers by increasing the availability of applications and techniques for treatment and by increasing the profit rate due to implementing the applications.

3.6 Challenges of IoT implementation*:* Six participants noted challenges with IoT including patient privacy and security and questions of how to make this technology safer, reliable and accessible. Four participants noted the potential for impediments due to the poor experience and shortage of staff. Moreover, a big challenge is the infrastructure, as the following participants explained:

" There are many healthcare organizations that have no health care information or even ERP systems, as well as there is poor experience in the IoT field, in addition to the cost of applying it"

(P9).

" I think of infrastructure … you've got hardware, software, even other resources are needed.
They don't necessarily have big data ready" (P10).

Three participants expressed concerns about the cost and maintenance of IoT devices. Additionally, they brought up the need for data storage and the ability to effectively analyze a huge cache of data. One participant noted patients may show apprehension and questioned how to train doctors and nurses as well as promote swift and correct clinical adoption.
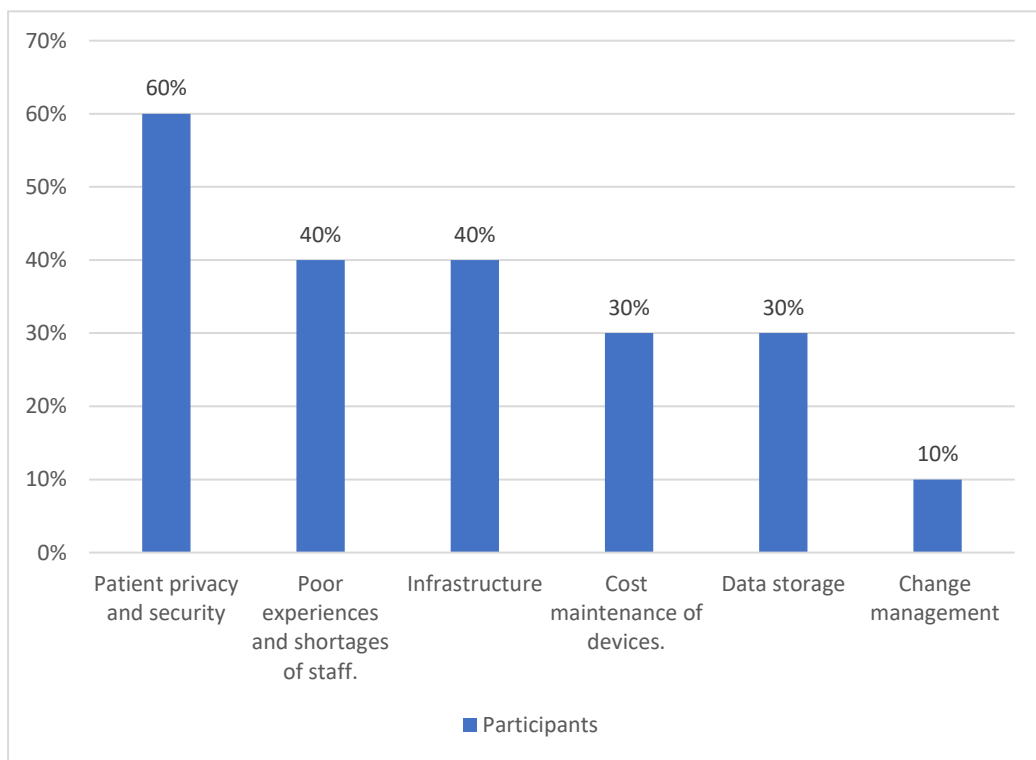

Figure 4: Challenges of IoT implementation.

3.7 Growth of patient satisfaction: All participants agreed on the expectation of an increase in the growth of patient satisfaction with IoT. For example, the following were noted:

" Very high. Applying IoT on KFMC systems will improve the clinical patient journey
in and outside the medical city" (P2).

" Easy to reach, easy to use and will improve awareness, the sharing of information, prevent complications, promote preventive care, and advance society health management" (P6).

"It will enhance the quality of treatment as well as the patient experience, especially in the seeking of treatment in the hospitals. For example, the introduction of a refill medication app. So, the patient will get his medication via a click and there is no need to go to the pharmacy and be in the line for one hour!" (P9).

3.8 Risks after applying IoT in medical cities: Six participants suggested risks that may present after applying IoT such as security—that is, specifically being able to confidently protect the patient's information from hacking and from being accessed by everyone. Four participants brought up concerns regarding patient data in terms of how to make this data available to use and the extent of its impact on patient safety. Four participants expressed the need for an accurate infrastructure setup and a disaster recovery plan for systems and patient data.
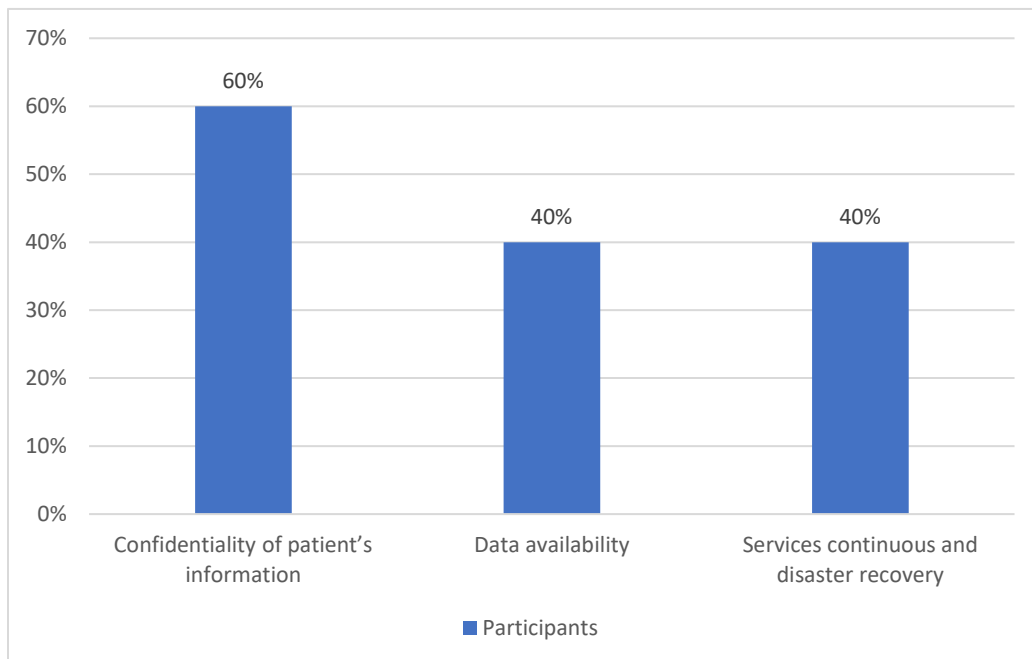

Figure 5: Risks after applying IoT in medical cities.

4. DISCUSSION

Advances in IoT play a significant role in health care systems and readily contributes to the development of medical information systems. However, IoT health care systems also represent one of the existing and important challenges that every country and its health care professionals face increasingly in the context of the need to find new ways to improve care protocols and practices. Big issues include the impact on the quality of people's lives as well as the growth of medical care costs, especially for patients with chronic diseases [9]. There is some of applications in the health care sector of IoT technologies in Saudi Arabia currently. These applications are largely used at this time to increase the quality of care for patients and enhance treatment solutions. Applications that gather data such as body temperature, blood pressure and wearable sensors designed to monitor many other body parameters can assist patients in their living activities. However, the implementation of a platform for IoT to promote data transfer from such sensors to a central server for information analysis is considered an obstacle to more widespread adoption [10].

Furthermore, the main challenges of connecting traditional applications and IoT applications in health care, as mentioned by Darshan et al., [11] were the process of considering a huge amount of data at a high speed and the need to strengthen the infrastructure. However, the cost-effectiveness of the analytics platform, the ongoing increase in the number of connected devices, and the standardization of the data gathered from devices could increase the chances of adoption. These processes require cloud computing for archiving the huge amounts of data that are gathered from sensors, devices along with ensuring that security and privacy for these data are maintained [11]. IoT health care in Saudi Arabia is expected to involve promises and visions of connectivity of the distant locations of patients physically. As well as the cooperation of hospitals and clinicians to coordinate the process of health care. In general, there are several challenges that IoT health care needs to overcome before it can be adopted in terms of the management of data, the scalability of systems, interoperability, standardization, security and privacy [12].

On the other hand, the future of IoT health care in Saudi Arabia will likely be successful and effective because it will more consistently promote patient health and quality of care. The responsibility to make a shift to IoT health care will be a joint effort from the Ministry of Health and the top management members of information systems and health informatics divisions in each hospital of Saudi Arabia. Indeed, the success of IoT health care in Saudi Arabia will face some

barriers due to the old-school mentality regarding patient care and the lack of specialists in the field of IoT. As well as the limited public awareness about IoT health care and regarding whether transferred data will be safe and trustworthy. These barriers first need to be overturned in order to successfully implement IoT health care in medical cities. Then, tools and platforms which enable the use of IoT in health care need to be introduced. Moreover, the security and privacy of patient' information as well as a backup plan in case the IoT health care system stops working should be explored.

In general, estimated initial three types of regulations or constraints must be established to implement and adopt IoT health care in the medical cities and hospitals of Saudi Arabia, as follows: technical constraints, administrative constraints, and legal constraints. The technical constraints cover the needs for automation and health information systems infrastructure. The administrative constraints consider required changes in the management and training of health care workers. The legal constraints constitute the need for clear policies on how data is exchanged, keep maintenance of patient privacy and business continuity.

4.1 Limitations

The study has several limitations. The IoT technologies lack experts in this area due to the limited number of participants in this research. Moreover, the target group of participants in the research seems to agree to participate initially and there is no response to schedule the interviews. These restrictions have led to the lack of expansion in research.

5. CONCLUSIONS

The present study reveals that state-of-art IoT technologies are largely not applied in the medical cities of Saudi Arabia. To this end, tailoring of solutions and the integration of health information systems with IoT is needed. Furthermore, the attainment of higher numbers of staff with more experience in this field is warranted. However, the present research highlights the promotion and use of IoT in medical cities should be more focused on training the users and pushing them to increase adoption of IoT. The initiation of real projects that apply IoT in health care should also be promoted. This study highlights the future opportunities, benefits, challenges, risks, and prospects for IoT-based health care applications that will hopefully be implemented in hospitals and medical cities in Saudi Arabia. These findings may also be useful for health care

professionals when implementing future IoT health care services in Saudi medical cities for superior patient management.

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