INTERNET OF MEDICAL THINGS (IOMT)-

IMPLEMENTATION, APPLICATIONS, DATA

MANAGEMENT AND CHALLENGES

Dissertation Submitted to

The IIHMR University, Jaipur

for the partial fulfilment for the award of the degree of

Master of Business Administration (MBA)

in

Hospital and Health Management

by

Pallak Khanna

Under the Supervision and Guidance of

Dr. Arindam Das

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DECLARATION BY STUDENT

I hereby declare that this dissertation titled **Internet of Medical Things(IoMT)-Implementation, Application, Data Management and Challenges** is the bonafide record of my original research work. I declare that it has not been submitted to any other university or institution for the award of any degree or diploma. Information derived from the published or unpublished work of others has been duly acknowledged in the text.

Pallak.

(Signature)

Name of Student – Pallak Khanna

Date-6th July

Date: 03-July-2021

Internship Completion Certificate

To Whom It May Concern

This is to certify that **Pallak Khanna,** student of **Indian Institute of Health Management Research (IIHMR)** has worked as **'**Product Analyst- Intern**'** with Karkinos Healthcare Private Limited, and has successfully completed the internship under the guidance of Mr. Manish Sharma, Chief Product Officer-Karkinos.

Internship Duration: 04th -February-2021 till 30th-April-2021.

We wish all the best.

Karkinos Heathcare Pvt. Ltd.

Pooja Sharma
Vice President-HR

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CERTIFICATE

This is to certify that dissertation titled **Internet of Medical Things (IoMT)-Implementation, Applications, Data Management and Challenges** is a record of the research work undertaken by Pallak Khanna in partial fulfilment of the requirements for the award of the degree of MBA Hospital and Health Management the IIHMR University, Jaipur under my guidance and supervision and his/her approach to the research study has been sincere, scientific, and analytical.

Faculty Guide
IIHMR University, Jaipur
Date

School Dean
IIHMR University, Jaipur
Date

Abstract

Background: The implementation of Internet of things in the health sector, particularly in managing Chronic Diseases has tremendous potential for improving the cost effectiveness, quality of care and efficiency of health systems specially in a Covid-19 world.

Purpose: The objective of this mixed methods systematic review of literature is to determine the role of Internet of medical things (IOMT) and its technologies in Healthcare along with its applications. This study also focuses on effective utilization of big data collected from IoMT to gain data-driven insights using Predictive Analytics. It also pinpoints a few challenges associated with IoMT and strategies to overcome them.

Data sources: The articles were reviewed after conducting an extensive systematic search on various major scientific database platforms: PubMed, IEEE Xplore, Cochrane, Google Scholar and ResearchGate. The articles that were shortlisted for review were published in English language between 2016 and 2021.

Study selection: Comprehensive articles and replicable studies involving IoTs in healthcare, chronic disease management, IoMT data management and predictive analytics were included.

Data extraction: The secondary data extracted includes material on the Implementation of IoMT in healthcare-technological architecture; applications/use cases of IoMT; IoMT Data Management and Predictive Analysis; implications and recommendations to overcome them.

Results: A total of 50 articles were covered in the review according to the inclusion criteria. The included articles were studied and an in depth analysis of various architectures for IoMT was carried out. Architectural detail along with relevant scientific evidence has been discussed. The major applications of the Internet of things in health care were also discussed. Managing IoMT Data through Predictive Analysis and gaining data driven insights to improve overall population of health is has been one of the key focus area of this study.

Conclusion: This systematic review study unveils the utilization of IoMT in the real-time management of chronic diseases by enabling early intervention. It includes the architecture, technologies, applications and challenges of IoMT in the Healthcare sector.

Acknowledgement

I would like to express my immense gratitude to our University, IIHMR, Jaipur Rajasthan, for giving me this opportunity of research work as a part of my dissertation. Our university left no stone unturned in helping the students to cope up with the curriculum in these most difficult times and unseen scenarios.

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Table of Contents

Abstract 1

Acknowledgement 2

Chapter 1-Introduction 4

1.1 Research Motivation 14

1.2 Research Question 15

1.3 Study objectives: 15

Chapter 2: Literature Review of Related works 16

Chapter 3- Research Methodology: 20

Chapter 4-Results and Discussions 27

4.1 Technologies enabling IoMT 27

4.1.1 Technical evaluation of IoMT Architecture 29

4.2. Applications of IoMT 32

4.3 IoMT Data Management 35

4.3.1 Strategies to manage IoMT Data 36

4.3.2 Insights from IoMT Data- Predictive Analysis using Machine Learning 36

4.4. Challenges of IoMT and Solutions 43

Chapter 5-Recommendations 45

Chapter 6-Conclusion 50

Bibliography 53

Chapter 1-Introduction

The digitization of information including health information and its utilization in conveyance of medical services has been developing rapidly across the world. The COVID-19 pandemic has been a focus for outstanding development of IoT in medical services. “A few rapidly advancing innovations are combining to impact the direction of IoT in medical care. There are a few challenges in innovation advancement, medical services conveyance just as issues identified with security of information, computerized partition, job of government and different partners, conduct and selection by clinical specialists and medical clinics”(2). This study aims to give an outline of the enhancement, implementation and challenges of IoT in the healthcare sector universally, the complexities of various variables impinging its present status and provides recommendations for proper enablement of this technology while managing the real-time health data that is being accumulated to gain data-driven insights.

Background on IoT

In this era of rapid scientific transformation, a few variables have prompted the coming of what is alluded to as the Internet of Things (IoT). The technological advancements include a massive technological upgrade for flexible processing power and mobile computing power for handheld devices, enhancements in "near field communications (NFCs, for example, Bluetooth low energy innovation, development of Rapid Frequency Identification (RFID) innovation, and lastly the expansion away from the limitations of an integrated circuit (chip) and big data clouds, such as those offered by Amazon and Google”(1). Costs and scalability have made a constant coordination that formed into a network of "associated figuring gadgets or things" across the globe with a distinct personality. This organization is alluded to as “ Internet of Things” (1)
“It is a network of physical objects that are connected through the Internet of Things—remotely-connected devices built with sensors, software, and other technologies” (1,2)

IoT has affected a huge number of regions and has led to what is prominently called "smart everything" including "smart homes", "smart gadgets and hardware", "smart autos" including driverless vehicles. The impact of IoT on the medical services industry has grown over time. (2)

IoT in Healthcare

In the recent past, human healthcare tends to become more preventative, predictive, personalized, and participatory, and the increasing digitization of healthcare underpins these trends. “IoT in healthcare refers to a network of connected medical devices that are able to not only generate, collect and store data but also connect with a network, analyse the data as well as are able to transmit data of various kinds such as medical images, physiological and vital body signatures and genomics data”

“To describe all medical devices and medical applications, a newer term has been introduced called Internet of Medical Things (IoMT)”(2). The terms IoT, digital health, and IoMT will be used interchangeably throughout this study.

IoMT: What Is It?

A connected infrastructure of medical devices, software, health management systems, and services is known as the Internet of Things.

“IoMT stands out from the rest for its use of internet-connected devices for remote patient monitoring, wearables, and stand-alone devices for remote patient monitoring coupled with the marriage of internet-connected medical devices and patient data. Deloitte reports that IoMT is gaining momentum as medical devices are becoming connected to the Internet of Things, generating, collecting, analyzing or transmitting health data or images, connecting to provider networks, and posting data to the cloud or internal servers”(3).

By streamlining clinical workflow management, medical devices and sensors can be connected to improve patient outcomes inside and outside the care facility.

Innovating healthcare through IoMT

As a result of this technology, fewer mistakes are made, the costs for care are lower, and diagnoses are more accurate. “Through smartphone applications, patients can send their health information to doctors to monitor disease progression and prevent chronic diseases”(3).

“An extensive study conducted by researchers at Cedars-Sinai Medical Center and UCLA demonstrated that Fitbit activity trackers can be used to measure heart rate and accelerometer data simultaneously in patients with ischemic heart disease. That might help explain why 88 percent of care providers have invested in remote patient monitoring, according to mHealthIntelligence”(4).

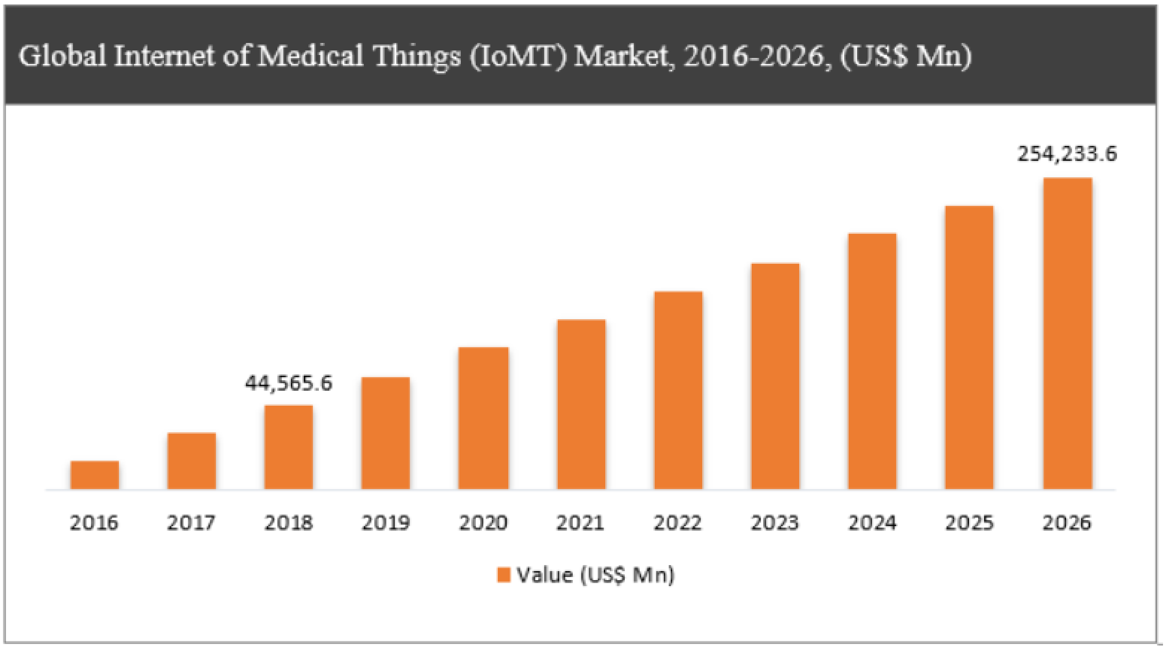
“With similar technology, we can eliminate in-person medical visits, which is helpful not only for improving patient experience, but also for reducing costs. IoMT is expected to save $300 billion in healthcare expenditures based on medication adherence and telehealth, according to Goldman Sachs”(5)

Additionally, IoM technology can also be beneficial in managing drugs by introducing smart pills with microsensors that transmit data to connected devices once they are swallowed.

“Proteus Discover, for instance, has developed smart pill capabilities to measure the effectiveness of treatment in order to boost clinical outcomes. The CorTemp pill, for example, is a device that monitors the internal health of patients, sending measurements such as core temperature via wireless transmissions that may be crucial if the patient is at risk of suffering a life-threatening condition”(5)

The growth potential of the IoMT

AllTheResearch estimates that the IoMT market size globally, “will grow to $254.2 billion by 2026, from $44.5 billion in 2018. According to the report, smartwatches and sensor-loaded smart shirts dominated the wearable device segment of IoMT in 2018, accounting for roughly 27 percent of global revenue”(3). (Refer Fig 1)



(Figure 1.1) Global Market of Medical Things (3)

With artificial intelligence integrated into connected devices, this area of IoMT is expected to grow even more in the future, allowing for real-time, remote measurement and analysis of patient data.

Other technologies that benefit from the expanded IoMT ecosystem include kiosks that enable connected patient monitoring. In rural communities, health care specialists are hard to recruit and retain, so such kiosks help clinicians monitor and treat patients remotely.

IoMT will become increasingly impactful no matter where a patient is or what their condition is. Connected medical devices will continue to reach not only patients but also clinicians throughout the most remote regions of the globe, improving access to care.(2,3,4)

The IoMT sector has been segmented into broad categories: (Fig 1.2)

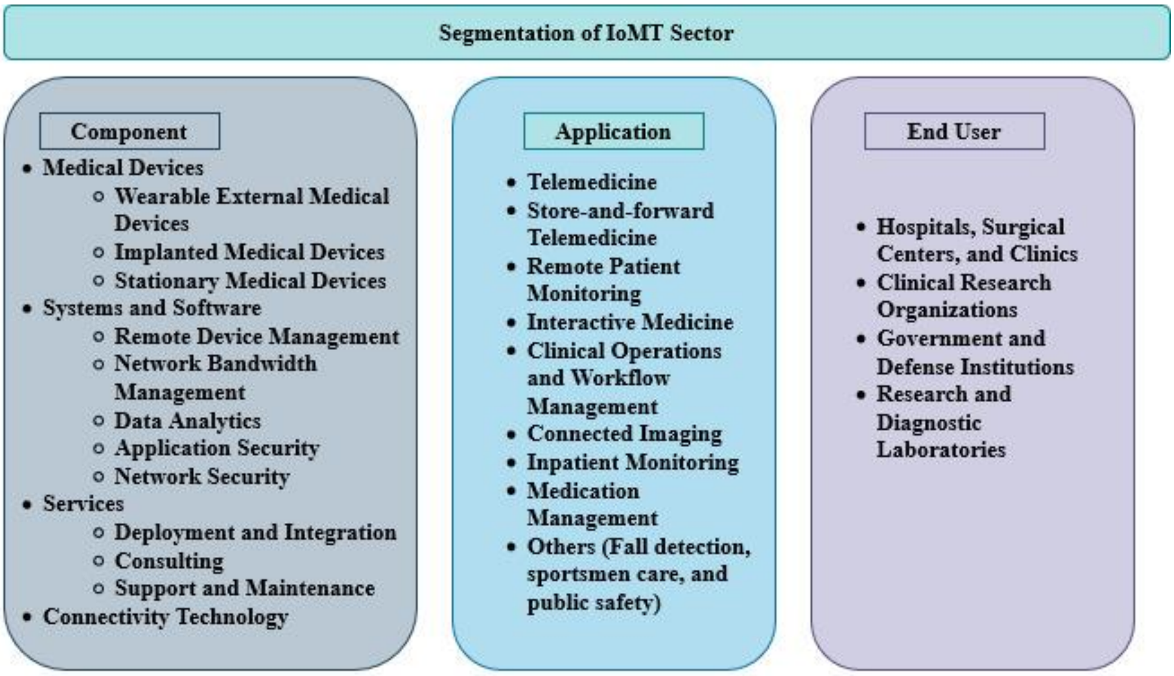


Figure 1.2 Segmentation of IoMT Sector(3)

IoT vs IoMT

What Makes IoMT Different?

Modern, connected appliances or devices are what are commonly referred to as the IoT. “For example, a smart doorbell with video feature works just like a regular doorbell - but with the added benefit of allowing homeowners to control the device from their cell phones. Also, they can see the entrance to their house through a live stream and speak to any guests who come.”

A wide range of devices, “from smartwatches to refrigerators to televisions and appliances, feature the same functionalities.”

There are many Internet of Things-branded products, however, which are meant for average consumers. In fact, this technology is not just useful for consumer products but can be applied to many different uses. As a result, platforms such as IIoT and IoMT have been introduced, with the technology offering a multitude of potential uses.(2)

The doctors and nurses in hospitals, for example, must constantly keep an eye on patients throughout the day while continuing to move around. “The medical professionals could access information from any location on campus by equipping medical equipment, sensors, and devices with a more connected network. The time saved would be used for life-saving activities”(2).

“The Internet of Things is the technology that makes this possible, but security and reliability must be incorporated as an essential component as well. The risk of streaming medical records and data is exponentially greater than what is in a refrigerator or what is playing on television”(7).

It's still important to keep sensitive information protected in the medical field, but it's especially important in this field. In the event of noncompliance, this could lead to huge fines and fees for commercial medical facilities.

How Does IoMT Compare to IoT?

IoT devices are installed in nearly three out of five healthcare companies, and seven out of eight companies plan to use it. “Approximately 70 percent of health care organizations use technology for maintenance and monitoring”(7). “A significant percentage of the technology's use is dedicated to monitoring patients. These statistics tell us that technology is being adopted at an increasing rate and that its usage is spreading rapidly. Though it may not necessarily be comparable with the IoT market as a whole. That's not true at all.” (2)

“IoMT, on the other hand, is still relatively young, with numerous applications and solutions yet to discover, deploy, and explore. The reason for this is that many organizations are cautious about adopting the technology, so they take their time preparing network infrastructure and rollouts before going live with it.

Because the industry understands how critical it is to safeguard confidentiality and data security, it is understandable why they are taking their time to adopt the technology. Although IoMT lags behind considerably, a lot of what's being done in the general IoT market will be applied to the medical and health care sectors. Endpoint security is just starting to gain traction for IoT, for example, and it will certainly be helpful for the healthcare market as well”(4,5,6,8).

“Although IoMT isn't yet widely adopted by organizations, it does have an edge in terms of security - primarily because it's being adopted slowly. Endpoint security, internal segmentation, advanced authentication policies, and real-time monitoring make it much less likely that medical data will be compromised. Comparing that to the generally unprepared nature of most deployed IoT systems, we can see the technology is more susceptible to hacking.”

Healthcare Services through Mobile Devices and Apps: Enabling Telemedicine

We are entering an era of information, where data and knowledge are key elements. A new era of the customer has begun, in which the customer will determine what he or she wants more than ever. “In this case, myTomorrows is an example of how business models are changing. It connects customers directly to pharma.”(4)

A "health selfie" will be taken with a device or app in this new era. Here are some examples:

- “The Myo, originally designed as a game controller, is now used in orthopedics to help patients exercise after fractures. The Myo lets patients monitor their progress while doctors can measure the angle of movement.”(4)
- “Zio Patch measures heart rate and electrocardiogram (ECG) and is FDA certified”(4).

What role does pharma play in all of this? There is evidence that pharmaceutical companies are shifting away from their traditional medicine-centric view. (4,5,6,9,11)

- “In a recent announcement, Glaxo stated that it will invest in electroceuticals, medicine that works by micro-stimulating nerves.”(5)
- “A robotic surgery program has been developed by Johnson & Johnson and Google. Furthermore, Philips and Siemens are collaborating on wearable devices, such as blood pressure monitors.”(6)
- “Novartis and Google are collaborating on sensor technology, including a smart lens and an adaptive blood glucose sensor.”(9,11)

“In addition to sensors providing pharma developers with valuable information, it is important to recruit patients who are appropriate for clinical trials. Body sensors are now rapidly making their way into the marketplace, and consumers and pharma will soon be able to access a wealth of data including pulse, blood pressure, and ECG, but also advanced data like inflammation and sleep patterns.”

“There have been a number of mobile applications that support device handling, including SleepBot and myDario. The Hacking Medicine Institute released RANKED Health, a program that evaluates and ranks health-related apps for mobile devices”(11).

Our phones and smart watches will likely replace our mail and WhatsApp in the near future as a way to check our health status more often. This is a typical situation which might involve an elderly patient is connected to several connected services streaming data to family members, a tele-carer and a physician while at home recovering from a medical condition

“Medical device company Medtronic recently announced that its diabetes prevention program will be resold by Canary Health, a digital health app company that specializes in modifying behaviors in diabetics. The partnership, however, goes beyond the mere resale of Canary Health's digital tools. There are a variety of elements involved. According to a Canary Health press release”(12), both companies “plan to create solutions based on Medtronic's devices, services and infrastructure, as well as Canary Health's suite of behavior-change programs, design expertise, and deep user engagement experience"(12).

The fact that “Canary Health” offers reimbursable digital tools must have attracted Medtronic. Increasingly, payers are looking for” ways to reduce their cost burden for chronic diseases such as diabetes that are innovative yet proven”(12).

“According to the Center for Disease Control and Prevention (CDC), participants in structured lifestyle change programs like Canary Health's, Omada Health's, or Noom Health's can cut their risk of developing type 2 diabetes by 58% (71% for people over 60 years old)"(5). “According to the CDC, "this finding was a result of a program that encouraged people to lose 5 to 7 percent of their body weight by eating healthier and participating in 150 minutes of physical activity a week".(5)

A wide range of stakeholders, including hospitals, doctors, patients, and payers, are trying to curb diabetes, which is an expensive, chronic disease. By doing so, companies go beyond simply treating the sick to actually delivering health care

“Due to advancements in video transmission technology, such as mobile communications and voice over internet protocol (VoIP), telemedicine grew rapidly by the mid-2000s, as the monitoring of patients far away was expanded. Furthermore, information collection conventions have been refined in recent years, particularly persistent information, which has led to the development of Electronic Health Records (EHRs), which capture the historical backdrop of a patient's clinical history, including drugs, vaccinations, indications, and current diagnosis”(6)

“Telemedicine is an essential tool for providing health care in geographically remote regions. Additionally, it acquired speed in delivering home health care to elderly patients with persistent conditions.(6) With the emergence of a middle-aged population in the created world, telemedicine's importance is growing. As a matter of fact, the notion of medical clinics in homes is on the rise, suggesting that expanding care is being given at home distantly. Telemedicine and EHR use have also contributed to a more patient-centered general practitioner-patient relationship.”(11)

“The new COVID-19 pandemic has shown the handiness of telemedicine meeting in breaking the pattern of disease spread and simple admittance to interview. It has been assessed that there has been a ten times ascend in teleconsultation in the USA because of the pandemic (16). The Center for Disease Control and Prevention (CDC) delivered a warning rule for utilization of telemedicine(17). This spray in utilization of telemedicine has additionally been seen in different nations, for example, China and Italy to name a few”(16).

The “Internet of Things (IoT)” has reproduced an assortment of new innovation arrangements, utilized across similarly as numerous dissimilar businesses. The

“Industrial Internet of Things (IIoT)” is basically IoT gadgets utilized inside development, improvement and mechanical conditions.

Additionally, the “Internet of Medical Things (IoMT)” includes associated gadgets utilized inside the clinical and medical services industry.

They vary from general IoT as far as use, yet additionally in plan. IoT is regularly more customer engaged, intended to give most extreme accommodation and ease of use. Different structures are more about exactness, dependability or more all, security.

All things considered, there's consistently the topic of how they stack facing each other. Is IoMT similarly as cutting edge and skilled as broad IoT? Why or why not?

Management of Chronic Diseases

Patients with chronic conditions can benefit greatly from the IoT when it comes to improving their health. Over 50% of patients with high-risk patients of congestive heart failure (CHF) have been cut down on re-admissions through remote monitoring, analytics, and mobile platforms. Chronically ill individuals benefit from the growing availability of affordable and easy-to-use equipment, like wireless scales and monitors that measure heart rate and blood pressure.

“The improvement in health likely to result from remote monitoring of patients with chronic disease may amount to $1.1 trillion per year by 2025, as some researchers estimate.”(6)

Consumers are becoming increasingly comfortable using IoT to monitor health, demonstrated by the rapid growth of fitness trackers like Fitbit®, as well as online fitness applications. The existence of these services has led to patients becoming more accustomed to managing their health online. Payers are implementing wellness incentives and discounts, and healthcare organizations are integrating them into customer engagement strategies.

“Several new technological advancements in chronic disease management are also being spurred on by the Internet of Things. People with disabilities can, for example, interact with care providers on a whole new level with connected wheelchairs, relaying health alerts to caregivers and letting manufacturers know when repairs need to be made. In a recent project, a team from the University of Missouri has developed sensors for monitoring the elderly's home in order to prevent falls by notifying them when they are at risk, and Dell Healthcare is collaborating with hospitals to deliver remote healthcare via tablets with integrated card readers."

"IoT has even greater potential to impact chronic disease management at the population level when combined with data analytics." Diabetes is one of the deadliest and most expensive chronic diseases. HealthNet Connect (HNC) developed a population-based diabetes management program to improve healthcare outcomes and reduce healthcare costs. The results are encouraging. Study participants were monitored and their vitals were collected over a six-month period to determine if regular teleconferencing and monitoring affected their health. "Key biomarkers, including HB A1C drop of 9.5 percent and LDL drop of 35 percent, were significantly lower in participants of the program. "Every 1 percent decrease in HB A1C can save $8,600 annually, and each 1 percent decrease in LDL can reduce coronary heart disease, which costs an average of $1 million per person over their lifetime"(6). "As a result of its demonstrated return on investment, HNC will continue the program, which improves members' access to physicians, improves their clinical outcomes, and provides them with improved knowledge of disease conditions."

IoMT's capabilities include more precise findings, fewer mistakes, and lower healthcare costs. Combining cell phone apps and health data sent from patients, the innovation enables specialists to review symptoms more easily and track diseases more effectively. Combined with information investigation, IoT has a much more prominent potential to impact ongoing infection on a population level. "For instance, Health Net Connect (HNC) has developed a diabetes management program that aims to improve clinical outcomes and medical care reserves for diabetes, which is one of the deadliest and most expensive chronic illnesses"(7).

1.1 Research Motivation

The” Internet of Medical Things (IoMT)” plays an integral role in the field of healthcare and has various applications. It has proven to have a significant impact on the population's health and improve telemedicine tremendously. In a developing country like India, people are yet to fully understand the capabilities and positive outcomes of IoMT. A lack of scientific evidence involving the extensive use of IoMT, and proper utilization of real time health data in developing under-developed countries was the major motivation behind this research.

Proper use of the real-time health data makes it junk and loses its potential. With predictive analysis, early health interventions are made possible which will have a drastic impact on the overall health of the population, especially in india. In India the incidence of Chronic diseases/NCDs is alarmingly high and” contribute to 62% of total deaths; majority of which are premature preventable deaths which account for a staggering 48% of mortality.”

The data collected from IoMT is invaluable to doctors and scientists if not put to proper analytics. IoT healthcare applications and medical devices receive a lot of data. Though this data is not worthy since it is unstructured and heterogeneous in nature. Its value is in quality, comprehensiveness and valuable insights. A wealth of information from thousands of patients provides better insight into symptoms if cleaned and analysed properly.

The use of IoMT and predictive analysis on the real time data can help to reduce the mortality due to chronic disease with early detection and early interventions. Apart from preventive care, IoMT can also help in self-management of diseases over the long run.

A lack of understanding of how IoMT works, contemporary technologies, applications and data insights from the Patient related health Data collected from IoMT, led to an urge for developing this research.

1.2 Research Question

This study is mainly focussed on answering the following research questions:

1. How can we integrate IoMT for chronic disease management to improve quality of care and overall population health?
2. How can we manage the big data that is collected from real-time monitoring using IoMT and gain data-driven insights using Machine Learning?
3. What are the challenges related to implementation of IoMT and how can we overcome them?

1.3 Study objectives:

The objectives of this research study are:

- To provide comprehensive literature review and scientific evidence for Implementation of IoMT and its technological architecture
- To discuss applications and uses cases of IoMT
- To use Predictive Analytics for IoMT Data Management and Analysis using Machine Learning
- To determine the challenges associated with IoMT and provide recommendations to overcome them.

Chapter 2: Literature Review of Related works

S. No.	Author	Year	Title	Contribution
1	Dadkhah M, et al	2021	Use of internet of things for chronic disease management: An overview	The present study provides an overview on the use of IoT for chronic disease management, followed by ranking different chronic diseases based on their priority
2	Farshad Firouzi et al.	2021	Towards Fog-driven IoT eHealth: Promises and Challenges of IoT in Medicine and Healthcare	propose that this requires a transition from the clinic-centric treatment to patient-centric healthcare where each agent such as hospital, patient, and services are seamlessly connected to each other. This patient-centric IoT eHealth ecosystem needs a multi-layer architecture: (1) device, (2) fog computing and (3) cloud to empower handling of complex data in terms of its variety, speed, and latency.
3	Bharati et al.	2021	Applications and Challenges of Cloud Integrated IoMT	A communication system is described then where a patient is monitored by the transmission of medical data via the wearable sensors on the patient. We propose a cloud integrated IoMT framework and compare it with the existing frameworks reported in the literature. Patients and their relatives, doctors can use this framework to get the health status of the patients and get alert in case of emergency conditions.
4	Oniani et al.	2021	Artificial Intelligence for Internet of Things and Enhanced Medical Systems	Internet of things (IoT), Big Data, and artificial intelligence (AI) are related research fields that have a relevant impact factor on the design and development of enhanced personalized healthcare systems. This paper discussed the review of AI for IoT and medical systems, which include the usage and practice of AI methodology in different fields of healthcare. The literature review shows that four main areas use AI methodology in medicine, such as heart disease diagnosis, predictive methods, robotic surgery, and personalized treatment.

5	Fadi Al-Turjman	2020	Intelligence in the Internet of Medical Things era: A systematic review of current and future trends.	This paper shows a generic IoMT framework that consists of three main components, data acquisition, communication gateways, and servers/cloud, to meet the aforementioned challenges. This paper discusses the opportunities and prospects of IoMT in practice while emphasizing the corresponding open research issues.
6	Habibzadeh et al.	2020	A Survey of Healthcare Internet-of-Things (HIoT): A Clinical Perspective	The availability of large amounts of data and computational resources is revolutionizing algorithms for individualizing inference and actions in health management. Throughout the paper, we use a case study to concretely illustrate the impact of these trends. We conclude our paper with a discussion of the emerging directions, open issues, and challenges.
7	Dash S. P.	2020	The Impact of IoT in Healthcare: Global Technological Change & The Roadmap to a Networked Architecture in India.	The review article provides an overview of the emergence of IoT in healthcare globally, the intricacies of different factors impinging its current status and recommends policy intervention for an optimal roadmap of IoT in healthcare in the Indian context.
8	Kelly et al.	2020	The Internet of Things: Impact and Implications for Health Care Delivery	The aim of this viewpoint paper is to provide an overview of the current IoT technology in health care, outline how IoT devices are improving health service delivery, and outline how IoT technology can affect and disrupt global health care in the next decade. The potential of IoT-based health care is expanded upon to theorize how IoT can improve the accessibility of preventative public health services and transition our current secondary and tertiary health care to be a more proactive, continuous, and coordinated system.
9	Javaid M et al	2020	Internet of things (IoT) applications to fight against COVID-19 pandemic	This paper depicts the current global challenges of COVID-19 pandemic and how Internet of Things (IoT) enabled healthcare system is useful for proper monitoring of COVID-19 patients, by employing an interconnected network. This paper aims to show how technology helps to increase patient satisfaction and reduces readmission rate in the hospital.

10	Kaur et al.	2020	A Survey on Machine Learning Prediction Algorithms Based on IoMT	prediction models are implemented for the prediction purpose and in the last phase the voting classification method needs to be designed for the respiratory disease prediction which give high accuracy.
11	Greco et al.	2020	Trends in IoT based solutions for health care: Moving AI to the edge	A review about the use and evolution of IoT solutions in smart health care is presented. The work discusses the role of AI in the internet of medical things context. Particular attention is given to solutions and approaches exploiting fog and edge computing for running AI algorithms.
12	S Rubí JN et al.	2019	Platform for Pervasive Healthcare Data Aggregation, Processing, and Sharing Based on OneM2M and OpenEHR. Sensors (Basel).	This article proposes an Internet of Medical Things (IoMT) platform for pervasive healthcare that ensures interoperability, quality of the detection process, and scalability in an M2M-based architecture, and provides functionalities for the processing of high volumes of data, knowledge extraction, and common healthcare services.
13	Mavrogiorgou A et al.	2019	IoT in Healthcare: Achieving Interoperability of High-Quality Data Acquired by IoT Medical Devices. Sensors (Basel)	in this manuscript a mechanism is produced for effectively addressing the intersection of these challenges. Through this mechanism, initially, the collection of the different devices' datasets occurs, followed by the cleaning of them.
14	Jothi et al.	2019	A Study On Iot And Data Analytics In Healthcare Systems	This paper examines the research efforts that lead to Big IoT data analytics and explains the overview of IoT, Big data and data analytics. Furthermore the various types of existing big IoT data analytics are discussed. Moreover, the association between IoT and data analytics is explained. The need of data analytics is also explained. Finally, several challenges and privacy issues brought by IoTdata analytics in the Healthcare industry are presented.

15	Dua et al.	2019	Ten Innovative Developments for the Internet of Medical Things (IoMT)	the Internet of Medical Things (IoMT) market is set to reach $158.1 billion in 2022, owing to the rise in demand for better-quality medical technology. Additionally, increased access to patient data is making it easier to incorporate IoMT devices seamlessly. The health care value chain is impacted across the board, making these 10 applications critical in the IoMT domain.
16	Nazir et al.	2019	Internet of Things for Healthcare Using Effects of Mobile Computing: A Systematic Literature Review	In this research, a systematic literature review protocol is proposed to study how mobile computing assists IoT applications in healthcare, contributes to the current and future research work of IoT in the healthcare system, brings privacy and security in health IoT devices, and affects the IoT in the healthcare system. Furthermore, the intentions of the paper are to study the impacts of mobile computing on IoT in healthcare environment or smart hospitals in light of our systematic literature review protocol.
17	Arthur & Badr et al.	2018	Internet of Medical Things: A Review of Recent Contributions Dealing With Cyber-Physical Systems in Medicine	This paper provides a comprehensive literature review of recent contributions focused on improving the Internet of Medical Things through the use of formal methodologies provided by the cyber-physical systems community. It also describes the practical application of the democratization of medical devices for both patients and health-care providers and challenges.
18	Koutras D et al.	2017	Security in IoMT Communications: A Survey. Sensors (Basel)	This paper focuses on main characteristics of IoT communication protocols used at the perception, network and application layer of medical devices. It examines the inherent security characteristics and limitations of IoMT-specific communication protocols, existing research and implementation gaps
19	Michalakis K et al.	2017	IoT Contextual Factors on Healthcare.	The paper identifies this context as perceived in healthcare applications and describe the context aware procedures. It also present an architecture that connects the sensors that measure biometric data with the sensory networks of the environment and the various IoT middleware that reside in the geographical area. Finally, it discusses the challenges for the realization of this vision.
20	Dimitriv et al	2016	Medical Internet of Things and Big Data in Healthcare	A number of technologies can reduce overall costs for the prevention or management of chronic illnesses. These include devices that constantly monitor health indicators, devices that auto-administer therapies, or devices that track real-time health data

Chapter 3- Research Methodology:

Study design

"A mixed methods research design is a procedure for collecting, analyzing, and mixing both quantitative and qualitative research and methods in a single study to understand a research problem."

This study is Mixed methods Systematic Review. This study was done by collecting and analysing relevant literature from various sources, based on the "**P**referred **R**eporting **I**tems for **S**ystematic reviews and **M**eta-analyses **(PRISMA)** guidelines. A method of systematic review was selected to ensure a reproducible approach to structure a critical synthesis of the existing and current evidence".

This study primarily focuses on extraction, interpretation, and evaluation of those research results that address the formulated research questions and align with the study objectives.

To obtain the research results from literature, both automatic and manual searches were conducted. Researches based on impacts/support, POC, applications/use cases, IoMT data perspective, architectural features and challenges of IoMT for managing chronic diseases were considered.

In this study, systematic review protocol is followed for reviewing research papers, articles, journals, from the most dependable databases. This method is adopted to reduce the possibility of researcher bias.

The study further aims to provide a comprehensive review to identify gaps in existing research which will include a review of the selected studies in depth.

Defining Review Protocol and Formulating research Question

This study was conducted to understand and review the literature, POCs, practical examples and applications regarding the proposed research. The focus of the current research work was to formulate the research questions that provided the starting point for further investigation.

The trends of IoT in the medical field have brought about innovation and effectiveness in the healthcare sector globally.

The applications and use cases of IoT in healthcare has been an interesting area of study, so it is mainly focused to formulate answers to the research questions mentioned in this study.

Defining Search Strategy.

In a systematic review, search strategy is the core of the study. The search is a very sensitive step, we would need to define keywords and synonyms for the keywords. The search strategy retrieves the studies that need to be analyzed for inclusion and exclusion criteria.

For this study, both Manual and Automatic search were conducted on electronic databases.

Search term or keywords were defined based on the following steps :

(a) Keywords were defined according to the topic of the study, research question and objectives.

(b) Alternative spellings, synonyms and abbreviations were identified for the keywords

(c) Keyword were also identified from books and relevant research papers

(d) Boolean operator OR was used for synonyms, alternative spellings and abbreviations

(e\ Keywords were followed by Boolean AND operators.

Search strings were formed after the analysis of the following keywords in order to retrieve the relevant information from the mentioned databases.

Keywords that were used for the search on various databases are “Internet of things,” “Internet of Medical Things,” “IoMT,” “Healthcare,” “Chronic Disease Management,” and “Non-Communicable Disease,” “NCD,” “Machine Learning,” “Predictive Analysis”

Two search string were formed based on combining the keywords in the following ways:

1. “(Internet_of_things OR IoT OR Internet_of_medical_things OR IoMT)”
2. “(Internet_of_things OR IoT OR Internet_of_medical_things OR IoMT) AND (Healthcare) AND (Chronic_Disease_Management OR Non-communicable_diseases OR NCD)”
3. “(Internet_of_things OR IoT OR Internet_of_medical_things OR IoMT) AND (Machine_ learning) AND (Predictive_Analysis) AND (Diabetes)”

Secondary Data sources

The articles were reviewed by conducting an extensive systematic search on various major scientific database platforms such as: “**Pubmed, Cochrane, Google Scholar, and IEEE Xplore”.** The references mentioned in the selected publications were also studied for a detailed review.

For Statistical Predictive Analysis PIMA Indian Diabetes Database (PIDD) was downloaded from Kaggle, an open source database.

Criteria for Inclusion and Exclusion

The following inclusion criteria was considered while selecting the literature for this review:

- IC 1: Articles that deal with Internet of things (IoT) or Internet of Medical things (IoMT) in the Health domain.
- IC 2: Articles that deal with IoMT applications
- IC 3: Articles where the primary emphasis is on contemporary Data Analytics Techniques and relevant technology.
- IC 4: Articles published between 2016 and 2021.
- IC 5: Articles published in English Language.

The following exclusion criteria was considered while selecting the literature:

- EC 1: Articles that did not define the topic properly.
- EC 2: Articles that dealt with IoTs but not in the health domain.
- EC 3: Articles published before 2016
- EC 4: Articles published in languages other than English.
- EC 5: Duplicates were not included

Study selection

The literature search and selection of research material was carried out in the following steps (Fig. 3.1):

1. A systematic search of research publications on scientific databases with keywords such as “Internet of things (IoT)” or “Internet of Medical Things (IoMT)” “Healthcare,” “Chronic Disease Management,”“Non-Communicable Disease,” “Machine Learning,” “Predictive Analysis”.
2. Relevant materials were chosen in accordance with the inclusion criteria by auditing and identifying important articles using titles and keywords.
3. The articles were screened on the basis of title, abstract and then full-text
4. Research materials that were shortlisted in the previous phase were re-examined for the review.
5. Cross-referenced material was searched and documented for a thorough analysis.

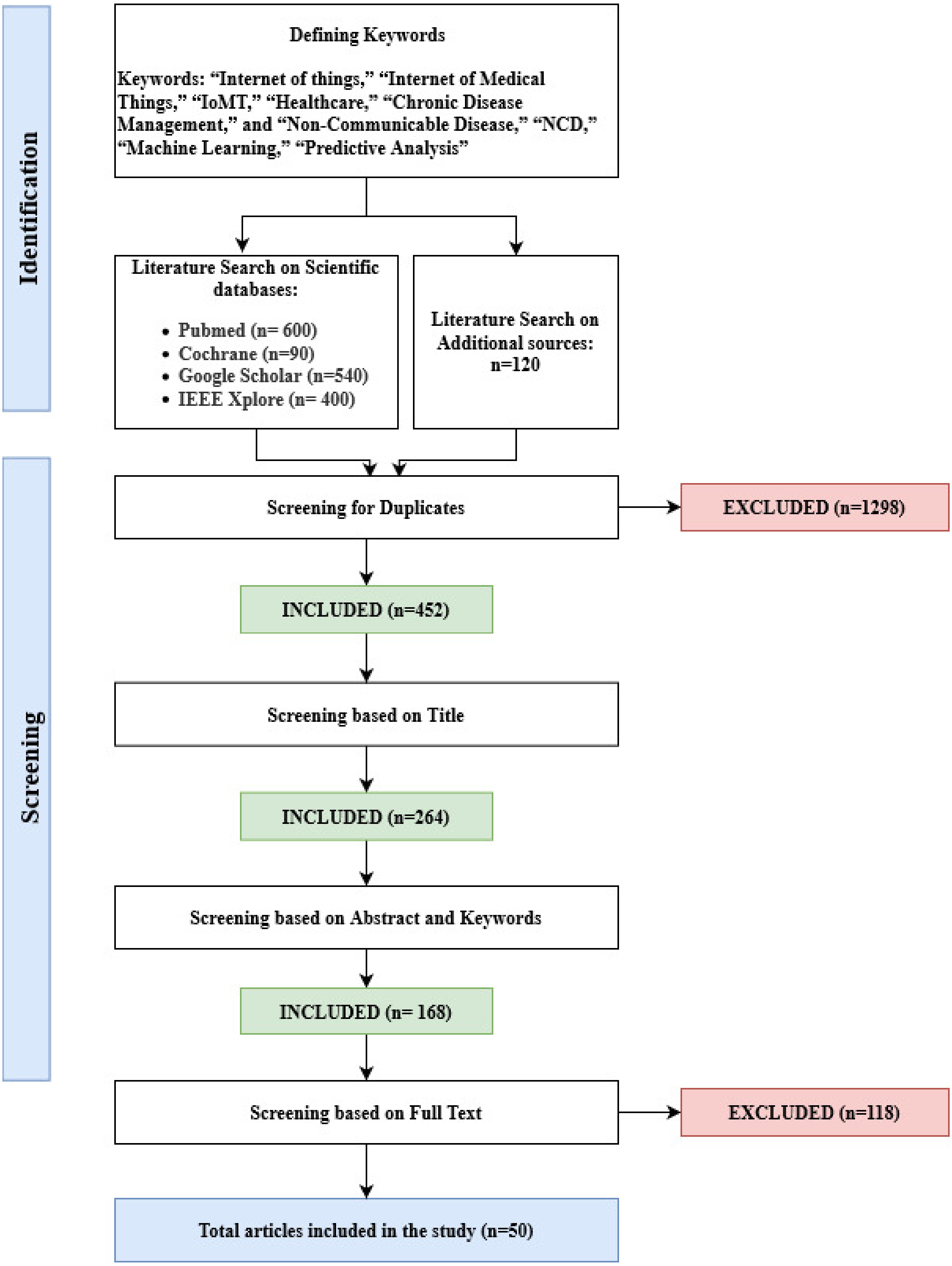


Figure 3.1 Flow Chart Of Methodology

Data Analysis:

The data analysis of this study has been done in two ways: Quantitative Metadata Analysis and Statistical Predictive Analysis.

Quantitative Metadata Analysis of the literature collected from various sources, the details of results included from each database have been depicted. This is a quantitative meta-analysis of the literature selected based on inclusion and exclusion criteria. In the figure, the analysis of search results and summary of included literature is depicted. The summary and source distribution have been depicted in the figure showing source distribution according to various types of journals, articles, blogs, conferences and ebooks. The data was stored and extracted from Zotero Software.

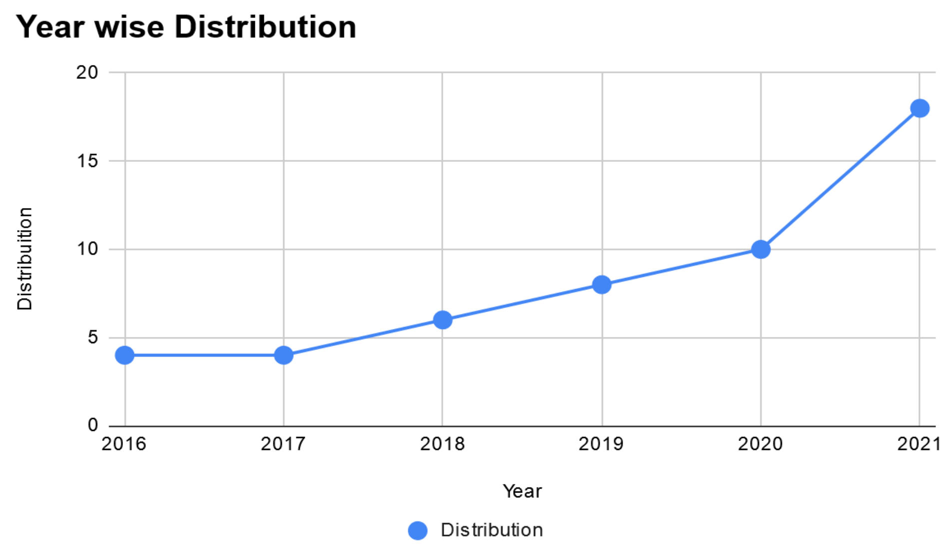


Figure 3.2 Year-wise Distribution of Selected Literature

The year-wise distribution of the included literature is given in the Figure 3.2. It was found that most of the studies that were included in this Report were published in the year 2021. It shows the number of publications per year corresponding to the research work presented. This section also summarizes the findings when the data was analysed quantitatively from multiple databases and the articles included after screening and filtering as shown in (Figure 3.3). As shown in Figure 3.4, list of research sources was also been identified and presented. According to the distribution of sources, the majority of papers were from journals, followed by articles and blog posts, conference proceedings, and extractions from book chapters.

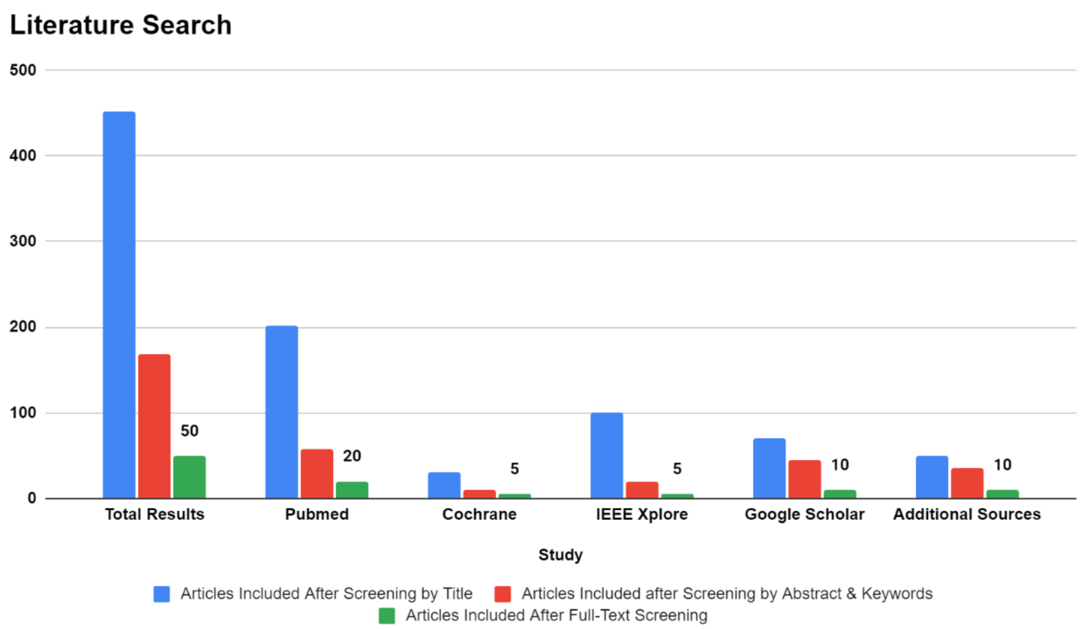
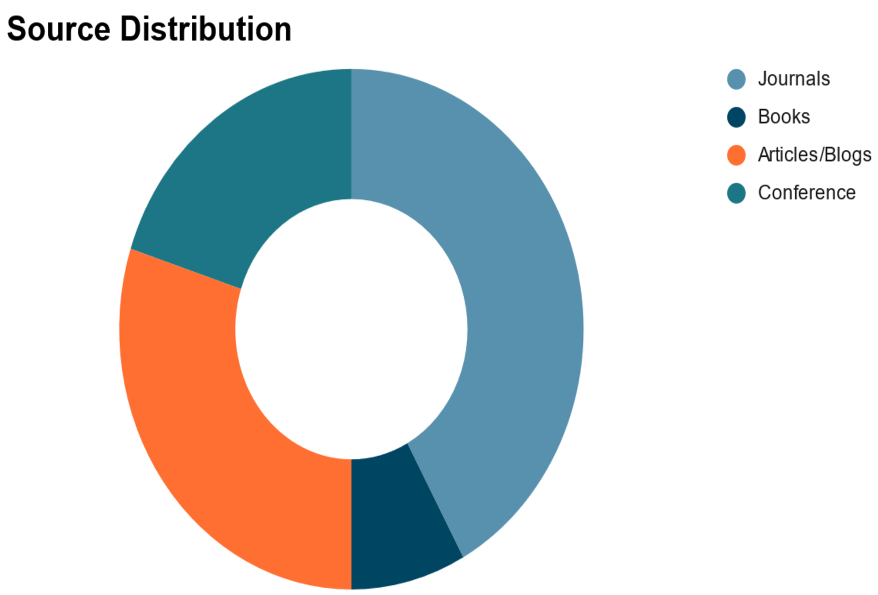


Figure 3.3 Literature Search and Figure 3.4 Source Distribution



Chapter 4-Results and Discussions

4.1 Technologies enabling IoMT

“For most IoT healthcare applications, typically, rely on sensors to collect and process data, cloud computing for long-term data processing, fog computing for short-term data processing, and wireless body area networks to connect sensors and data transmission devices, such as routers and gateways, to each other.”(7,10)

“With the development of information technology (IT) and medication integration, it has become possible to provide affordable, high-quality healthcare at home. Customers can save almost 20–50% of the costs. Mobile computing is one of the technologies included in the Internet of Things. Affordability of healthcare can be improved by the advancement of mobile technologies such as 4G as well as 5G.” PwC's 2017 survey found that 64% of healthcare organizations in India were investing in IoT technologies. (7,10,11)

The findings about each of these technologies are discussed in this section. Summary of the findings are given below(Table 4.1.1)

Table 4.1 Technologies Enabling IoMT (8,11,26,30,27)

Technology	Description
Sensors	IoMT relies on sensors for its functionality. Both clinical and non-clinical scenarios can benefit from IoMT. IoMT is used to monitor patient vitals in a clinical setting, including temperature, ECG, blood pressure, and blood oxygen saturation using sensors. This allows for continuous monitoring of health vitals for patients as well as providing physicians with dashboards to monitor and visualize the patient-related health data. Generally, sensors/things in healthcare can be divided into two categories: i) Clinical and ii) Non-clinical. A clinical sensor may also be classified as either wearable or implantable. Besides asset or equipment tracking sensors, location-based sensors, and legacy device sensors can also be classified under non-clinical sensors.
Cloud Computing	In cloud computing, resources are configurable and can be accessed remotely, anywhere and anytime through the Internet. Resources are monitored and billed on a pay-per-use basis. IoT is enabled by cloud computing. The processing layer, also referred to as the middleware layer, is a component of the IoT architecture. The IoMT generates a huge amount of data, which can be stored and analyzed with the help of cloud infrastructure. Cloud computing provides an almost infinite number of resources at data centers, which enables healthcare stakeholders to gain helpful insights from data which is analyzed and then stored for later use. Physicians can monitor the health of their patients, whose information is collected through various sensors and stored in the cloud.
Fog Computing	With fog computing, data processing can be moved from the cloud to sensors. Physicians and clinicians will be able to provide emergency health care due to the reduction of latency. Cisco coined the term fog computing to describe how sensors and network gateways or local gateways are used to store and process data. Fog nodes provide monitoring, preprocessing, storage, and security features. The monitoring facility allows the node to monitor the resources and services it provides. The preprocessing function allows the fog node to analyze basic data, which is critical for providing emergency healthcare.
Wireless Body Area Networks (WBANs)	In IoT architecture, WBAN is probably the technology responsible for communication at the transport layer. IEEE standards such as IEEE 802.15.6 and IEEE 802.15.4j, which are standardized for medical WBANs, are used. It offers speed, accuracy, energy conservation, and reliable communication between sensors and actuators within, on, or close to the human body. By using different sensors to monitor a patient's vital signs, WBANs can help to reduce healthcare costs and improve quality. Data rates range from narrowband, 75.9 Kbps, to ultra-wideband, 15.6 Mbps. Wireless Local Area Networks (WLANs), Zigbee, mobile networks, Bluetooth, Wireless Personal Area Networks (WPANs), and Wireless Sensor Networks (WSNs) are compatible with WBANs. An important application of WBANs in healthcare is improving the patient's quality of life.

4.1.1 Technical evaluation of IoMT Architecture

The technical evaluation of IoMT architecture was done by reviewing the existing literature and comparing the various architectures and the technological layers present within each of these architectures. Different architectures are compared based on their number of layers, complexity, data reliability in the fog layer, and their ability to support real-time applications. Based on evaluating and comparing different architectures, the best-suited architectures for IoMT have been found and outlined in this section.

The healthcare industry faces several applications that require immediate medical attention, such as diseases related to the heart or when providing healthcare for people who have been involved in life-threatening accidents. When situations like these arise, we need a real-time and critical response with significantly lower latency. In general, data is transmitted, processed, and returned from the cloud with significant delays.

We can reduce latency by using fog computing, which brings processing and storage resources closer to the sensors. In healthcare solutions, cloud computing is largely used for decision making. Fog computing is increasingly being considered for time-critical healthcare applications in recent years.

This article discusses architectural solutions used in recent years and their popularity.

Evaluation of some architectural solutions have been discussed in this section.

1. “Cerina et al.(16) proposed a multi-level architecture that takes advantage of fog computing and context awareness. A field-programmable gate array (FPGA) was used as a fog node by the authors”. The architecture consists of four layers, namely,

“i) interaction layer

ii) mesh layer

iii) fog layer

iv) cloud layer“

2.”For time-critical healthcare applications, the authors suggested removing the mesh layer. Nandyala et al. (17) proposed a 4-tier architecture for real-time ubiquitous healthcare monitoring”. The four tiers are:

“i) smart devices tier,

ii) fog tier

iii) core tier,
iv) cloud tier”

3. “CISCO's fog architecture heavily influenced this architecture. As part of the core tier, Verma et al. (18) suggested a five-layer fog-based architecture for remote patient health monitoring.” The layers are:

“i) data acquisition layer
ii) event classification layer
iii) information mining layer
iv) decision making layer
v) cloud storage layer”

4. “The study by Villalba et al. (19) analyzed the security of IoT-based medical services. The proposed engineering includes a cloud where registration is done, but no haze devices were found during the security investigation”.

5.”In a cloud-based solution, V.S. Naresh et al. (20) addresses the latency issues. The architecture contains three layers:
i) sensing layer
ii) fog layer
iii) cloud layer“

“Both time-critical healthcare applications that require an emergency response as well as non-time-critical healthcare applications can be developed with this architecture. Different sensors are used to monitor the health vitals of patients and elderly people in the sensing layer. An application data file is stored in a filtered or analyzed form on a transient storage server in the fog layer. It is also possible to implement security and privacy policies at a local gateway. Once the data has been transformed, it is sent to a border gateway, which forwards it to the cloud layer.
Cloud data can be stored permanently on servers, or medical personnel can use it to make decisions based on its analysis.”

The findings of the comparative analysis have been summarized below(Table 4.1.1)

Table 4.1.1 Comparative Analysis of IoMT Architectures (16,17,18,19,20)

Reference	No. of Layers	Complexity	Data Reliability	Real-Time Application Support	Security
Cerina et al.	4	Moderate	Low	Moderate	High
Nandyala et al.	4	Moderate	Low	Moderate	High
Verma et al.	5	High	Low	Moderate	Moderate
Villalba et al.	2	Less	Low	Low	Moderate
V. S. NARESH ET AL	3	Less	High	High	High

After the comparative analysis of the existing architecture, it has been found that the **Fog-Based architecture proposed by V.S. Naresh et al** (Figure 4.1.1)is most suitable for IoMT.

Having a low level of complexity, this architecture is designed to be flexible in how certain functions and modules are implemented at different layers. In the fog layer, data reliability is high since it is determined by the availability of clusters and distributed computing. In this architecture, the reliability of data at the fog layer was emphasized, which is crucial to applications in emergency care. A real-time application needs to support the fog layer since it exists and a lot of work is being done at this layer. “The value of security is also high based on the number of layers.”(20)

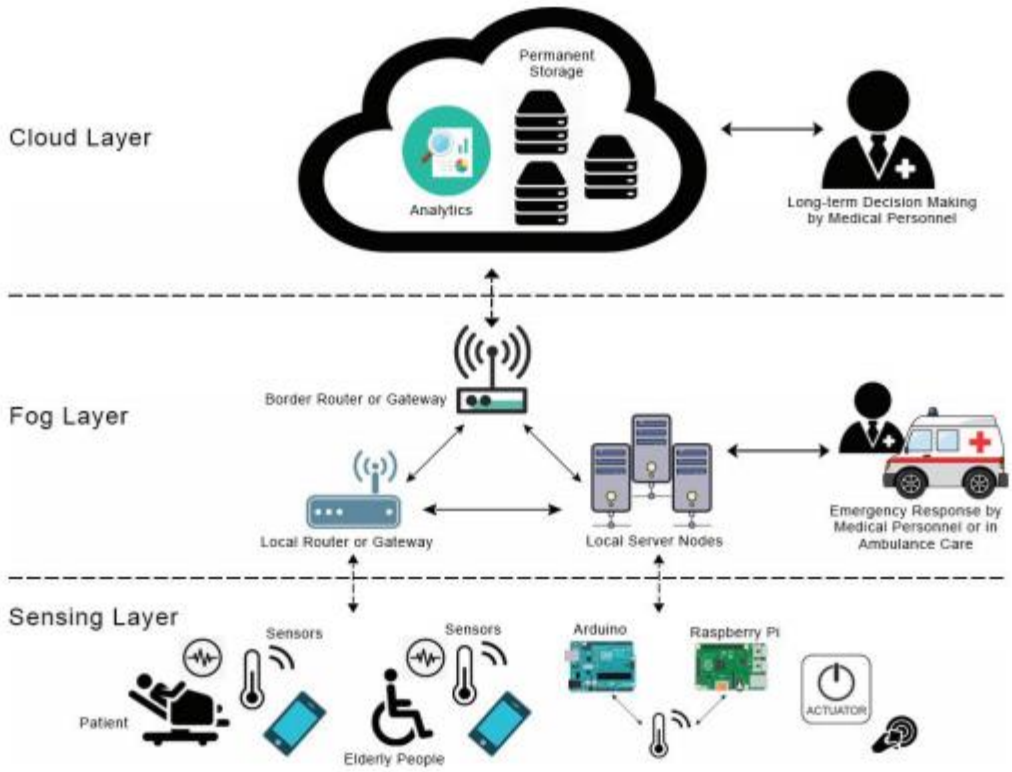


Figure 4.1.1 (19)

4.2. Applications of IoMT

A comprehensive review of literature pertaining to the IoMT applications and its related technologies will be presented in this section. A number of applications can be grouped into categories with common themes and scope, such as (26,27,28,31):

i) Real-time Remote Patient Monitoring

ii) Telehealth or Telemedicine

iii) Prevention, Prediction and Management of Chronic Disease

iv) Home and Geriatric healthcare.

Below are detailed discussions of these healthcare application categories as well as the role of IoT and related technologies.

Real-time Remote Patient Monitoring

Providing real-time healthcare services requires “continuous monitoring of various health vitals, such as temperature, heartbeat, and blood oxygen”. On a human body, sensors can measure different parameters through the Internet of Things. “This data can be analyzed in order to suggest the right medication in an emergency. An e-health system was designed by Shanin et al.(20) to monitor ECG, heart rate, foot pressure, and temperature, continuously. “Flexibility and low power consumption characterize the system. For emergency healthcare, GPS, and RFID are used to track the location of patients”. “The Arduino Uno microcontroller unit (MCU) and Thingspeak middleware were used for data analysis”. A system developed by Swarov et al. (21) “uses DS18B20 digital thermometer sensors and Sunroom blood pressure/heart rate sensors for real-time health monitoring. In addition to Bluetooth Low Energy, other modes of communication were used to transmit health data, including WiFi”. It was observed that “WiFi has a latency of nearly 5 minutes, while BLE has a latency of under a second. Rathore et al (22) proposed using Apache Spark and Hadoop to process huge volumes of data generated by sensors to reduce latency in a real-time emergency response system”.

Telehealth or Telemedicine

The Internet and Communications Technology (ICT) can be used to provide healthcare remotely, also known as telemedicine. “In addition to reducing the operational costs incurred by the medical personnel, this improves the health efficiency of the patient. Louka and Hosni presented a smart healthcare monitoring system that utilizes neural networks and fuzzy systems to analyze data collected by sensors such as temperature, ECG, heartbeat, pressure, and pulse oximeter. Through the GSM module, the data gathered by the sensors is forwarded to Azure IoT Hub and processed by the Fuzzybased Inference System (FBIS). Doctors can use this system to provide emergency healthcare using a remote health app and M2M patient monitoring system. Rohokale et al. proposed a system of monitoring vital signs like blood pressure, sugar levels, and abnormal cellular growth for rural people. RFID tags are worn by patients as identification. A remote healthcare center receives alerts when any health parameters are abnormal, and staff then takes the necessary actions”(23,24).

Chronic Disease Prediction and Prevention

“Diabetes, cardiovascular ailments, and cancer are among the most common chronic diseases in the world, as they are responsible for more than 70% of deaths and more than 50% of disease burdens. A new approach to tackling chronic diseases uses sensors, data, and algorithms along with medical specialists in a four-block framework: (a) Sense - collect biological signals in hospitals and at home; (b) Profile - combine multiple sources of information to create a comprehensive picture of a patient's health; (c) Detect -- analyze the profile, or even raw data, to find chronic diseases; (d) Monitor - manage the patient's health.” “Onasanya and Elshakankiri (26) present different types of architectures and frameworks for supporting IoT-based healthcare solutions for cancer patients. There is a focus on cloud services, which use big data technologies for data analysis, and on Wireless Sensor Networks (WSN), which are communication technologies that support a large number of sensors.”

A trend is seen where the major technology companies are investing in healthcare through the creation of “their own smartwatches and fitness devices, acquiring companies in this space, investing in health insurance startups, partnering with hospital systems or venturing into the pharmacy industry. It is also possible for all three of these to provide access to patient health data (profile), developing algorithms that can analyze medical data and images to diagnose diseases (detect), and partnering with the medical community to run end-to-end navigator programmes (monitor)”(26,27)

Manufacturers of medical equipment are leveraging IoT (Internet of Things) to reduce the distance between disease diagnosis and treatment.

In order to achieve this, it will be necessary to develop portable ultrasound devices, enable wireless live streaming using glucose monitors, and incorporate AI/ML algorithms into imaging equipment for proactive monitoring and intervention.

Home and Geriatric healthcare

“The Internet of Things and related technologies can be deployed at homes to monitor elderly patients who can't move quickly and take longer to reach hospitals for regular or emergency health care. Health monitoring systems for active and assisted living were proposed by Abdulgawad et al. (27), where various types of sensors collect data and transmit it to the cloud for data analysis. To demonstrate their functionality, a prototype was created a sensor system with six types of sensors, a BLE indoor positioning module, sensor interface circuits, a Raspberry Pi as a microcontroller, WiFi transceivers, and a cloud server. An evaluation of the prototype's performance is used to determine its efficiency.” “Yang et al. (28) suggested a personal healthcare system for wheelchair users who live alone. IoT and Wireless Body Sensor Networks (WBSNs) are used in this system to provide efficient healthcare to wheelchair users. In order to monitor the patient's health in real time, sensors measuring heart rate, ECG, pressure, nodes that sense the environment, and actuators are deployed around and on the patient.”

4.4 IoMT Data Management

IoT offers new possibilities in patient care through real-time health monitoring and access to patient data. By using these data, healthcare stakeholders can improve patient health and experiences while making revenue opportunities and improving healthcare operations.

Over the past decades, IoT devices have generated enormous amounts of data. “A lack of analytic power makes such types of data useless. Analysis of huge amounts of data has helped people gain a valuable perspective on data generated by IoT devices. These solutions are still in their infancy, and there is no detailed survey of the field. This section presents an evaluation of Big IoT data analytics and provides an overview of Predictive Analysis using Machine Learning”(33,37,40).

An enormous part of the data collected from IoMT exists in unstructured or semi-organized structure. The unpredictable, dynamic and heterogeneous attributes of the data makes the extraction of valuable information extremely difficult when traditional data analytical tools and techniques are applied. Thus, there is a limited human capacity to process this information without compelling decision support. This demands the requirement for integration of Machine Learning in the healthcare sector to manage IoMT.

4.4.1 Strategies to manage IoMT Data

"Leading IoT platforms must provide simple, powerful access to IoT devices and data so designers can rapidly compose analytics applications, visualization dashboards, and mIoT apps." Leading platforms must be able to enable the following five capabilities:

(1) Global connectivity: With an IoT platform, we can easily connect our devices, apply cloud-based analytics to gain insights, and apply device management functions.

(1) Simple device management: Management of a device in an efficient and effective way can improve availability, increase throughput, minimize unplanned outages, and reduce maintenance costs.

(4) Technology integration: intelligently transform and store IoT data. Data is able to be easily pulled in the cloud thanks to APIs, which bridge the data-cloud divide. Rich analytics are used to extract the essential values from data ingested from various sources and platforms.

(4) Insights from IoMT Data: Get insights from an enormous amount of data to make better decisions and optimize operations. Monitor and respond to current conditions using real-time analytics. Utilize cognitive analytics to understand situations, reason through options, and adapt as conditions change. Easy-to-understand dashboards make it all easy to understand.

(5) Reduction of risk: From a single console, alerts and incidents can be acted on anywhere in the organization.

4.4.2 Insights from IoMT Data- Predictive Analysis using Machine Learning

The Internet of Medical Things (IoMT) can be used continuously to collect data sets, and the technology is extremely useful in predicting and dissecting clinical data. Machine learning algorithms are currently used for a variety of purposes, for instance, driving forecast, video surveillance, face recognition, spam and malware sifting, item suggestions, and online extortion identification. Information is assembled using distinct web sources which are consolidated to frame one organized dataset. It will be necessary to separate the highlights of the dataset in order to determine the relationship between the characteristic and the objective set. To ensure high precision, different forecast models are developed using Ensemble techniques for Predictive Analytics.

Predictive Analysis for Diabetes Mellitus

Globally, 382 million people suffer from diabetes, according to the International Diabetes Federation (IDF). The impact of diabetes has grown dramatically in the last few years, making it a global health threat. Diabetes has been steadily climbing up the list as a leading cause of death. By 2045, there will be 629 million people affected, representing a 48% increase.(45) Diabetes, however, is largely preventable, and can be avoided with the help of early prediction and intervention. Additionally, early invertentions can reduce the risk of heart disease and cancer. Therefore, a prognosis tool for predictive analysis is imperative that can assist doctors in detecting the disease early and recommending lifestyle changes to halt its progression. A Predictive Analysis can be performed on data collected by medical devices and medical apps. Patient-related health data can provide insights that are unimaginable, and when used properly can have a tremendous impact on the overall population.

“The goal of machine learning is to develop algorithms and techniques that will allow computers to learn from past experiences and gain intelligence. Statistical learning is closely related to Artificial Intelligence (AI). As a result of the learning process, the system is capable of recognizing and understanding the input data, so it can make predictions and make decisions accordingly” (5,43,45). Data is collected by different means, using different sources, in order to learn. After preparing the data, the next step is to reduce its dimensionality by removing the irrelevant data (or selecting the data that is of interest) and to fix any data-related issues.

The system can make decisions because a large amount of data is being used for learning. In order to analyze the data and retrieve the knowledge from the past experiences, algorithms are designed using logic, probability, statistics, controlling theories etc. The next step is to test the model to determine its accuracy and performance. “Finally, we can improve the model by using new rules or data. Pattern recognition, classification, and prediction are all accomplished using machine learning. Among the diverse applications of machine learning are: a search engine, ranking web pages, detecting email, tagging and recognizing faces, showing related ads, character recognition, gaming, robotics, disease prediction, and traffic management. The essential learning process to develop a predictive model. A large amount of medical data is analyzed automatically using machine learning algorithms these days. One example of ML's use in biomedicine is the diagnosis of liver disease, detection and classification of skin lesions, assessing cardiovascular risk, and analyzing genetic and genomic information.”(43,45)

“A SVM algorithm was successfully used to diagnose liver diseases have where classifiers such as support vector machines (SVM), logistic regression (LR), and Nave Bayesian (NB) were used to diagnose major depressive disorder (MDD) from EEG datasets”(45).

This model is implemented using supervised machine learning techniques in Python for the Pima Indian diabetes dataset to understand patterns for knowledge discovery. The data presented here pertains to Pima Indian medical records regarding diabetes onset among the population. Multiple independent variables are included along with one dependent variable, i.e. the class value of diabetes as a 0 or 1. A performance model based on support vector machines (SVMs) is presented and discussed in this work.

An example of IoMT Data for Predicting Diabetes Mellitus using Machine Learning is demonstrated in this study and the findings have been summarized below:

The predictive analysis was performed on “Pima Indians Diabetes Database (PIDD)” which is sourced from “UCI machine learning repository on Kaggle.” Google Colab was used, with Python as a programming language to run the ML algorithm.

“SVM Support vector machines (SVM) are used in both classification and regression. SVM models put data points on a space, then group them, and points with similar properties are grouped together. “The given dataset is treated as a p-dimensional vector in linear SVM, which can be divided by the maximum of p-1 hyperplanes. When dealing with classification or regression problems, these planes serve to separate data surfaces or establish boundaries among data groups

For the prediction, a Support Vector Machine (SVM) classifier was used. It has a low accuracy and a high execution time, according to literature. Diabetes predictions will be improved by using a voting-based classification approach. The proposed method will be implemented in Python, and accuracy and precision will be evaluated. Based on the data collected from the patient, this model can distinguish between those who are diabetic and those who are not.

Steps followed for building a Predictive Model using Support Vector Machines:

Step 1: Importing python libraries
Step 2: Data collection and Analysis

- Loading the diabetes dataset to a Pandas DataFrame
- Counting the number of rows and columns
- Statistical Analysis of the Data, Mean and Standard Deviation

Step 3: Data Standardization
Step 4: If data is not classified then it will be classified into training data and testing data. Step 5: Apply SVM classifier for prediction.
Step 6: Model evaluation based on accuracy score
Step 7: Making a predictive system based on this Classifier

The data set have been partitioned into two parts (training and testing). Training of the was done with 70% training data and tested with 30% remaining data.
Evaluation of the model was done by measuring the accuracy. Accuracy indicates our classifier is how often correct in diagnosis of whether patient is diabetic or not.

Description of the Dataset that was sourced for the study(Table 4.4.1): This dataset is originally from the “National Institute of Diabetes and Digestive and Kidney Diseases”. The objective is to predict based on diagnostic measurements whether a patient has diabetes.

Several constraints were placed on the selection of these instances from a larger database.

- “Pregnancies: Number of times pregnant
- Glucose: Plasma glucose concentration a 2 hours in an oral glucose tolerance test
- BloodPressure: Diastolic blood pressure (mm Hg)
- SkinThickness: Triceps skin fold thickness (mm)
- Insulin: 2-Hour serum insulin (mu U/ml)
- BMI: Body mass index (weight in kg/(height in m)^2)
- DiabetesPedigreeFunction: Diabetes pedigree function
- Age: Age (years)
- Outcome: Class variable (0 or 1)”

Table 4.4.1 Description of Dataset

S. No.	Attributes	Values
1	No. of time pregnant (NTP)	Numerical Value
2	Plasma Glucose Concentration (PGC)	Numerical Value
3	Diastolic Blood Pressure	Numerical Value(mm Hg)
4	Triceps Skin Fold Thickness (TSFT)	Numerical Value
5	Serum Insulin (SI)	Numerical Value (mu U/ml)
6	Body Mass Index (BMI)	Numerical Value (weight in kg/(height in m)^2
7	Diabetes Pedigree Function (DPF)	Numerical Value
8	Age	Numerical Value
9	Diagnosis of type 2 diabetes disease	Boolean Value Yes=1 No= 0

Statistical Analysis was performed on this dataset and the results are as follows(Table 4.4.2)

Table 4.4.2 Results of statistical Analysis

S. No	Feature	Mean	Standard Deviation
1	No. of time pregnant (NTP)	3.8	3.4
2	Plasma Glucose Concentration (PGC)	120.9	32
3	Diastolic Blood Pressure	69.1	19.4
4	Triceps Skin Fold Thickness (TSFT)	20.5	16
5	Serum Insulin (SI)	79.8	115.2
6	Body Mass Index (BMI)	32	7.9
7	Diabetes Pedigree Function (DPF)	0.5	0.3
8	Age	33.2	11.8

Evaluation of the Model based on accuracy (Figure 4.4.2)

Accuracy Score

```
[ ] # accuracy score on the training data
    X_train_prediction = classifier.predict(X_train)
    training_data_accuracy = accuracy_score(X_train_prediction, Y_train)
```

```
[ ] print('Accuracy score of the training data : ', training_data_accuracy)

    Accuracy score of the training data :  0.7866449511400652
```

```
[ ] # accuracy score on the test data
    X_test_prediction = classifier.predict(X_test)
    test_data_accuracy = accuracy_score(X_test_prediction, Y_test)
```

```
[ ] print('Accuracy score of the test data : ', test_data_accuracy)

    Accuracy score of the test data :  0.7727272727272727
```

The Accuracy of the model was found to be 77% which is considered to be a good accuracy score. A score more than 70% is optimal for building a predictive model. On the PIMA dataset, the model has a 77% accuracy rate for diabetes onset. In this way, this proposed system provides healthcare officials with an effective prognostic tool. Developing an automatic prognosis tool based on these results may help in detecting diseases at an early stage

Building Predictive System

A predictive system based on SVM was successfully implemented. To test the predictive system data points for two people were taken. The predictive model correctly predicted the outcome when the data points were entered.
If the outcome of the predictive model is 0 then the person is not diabetic and if the outcome of the predictive model is 1 then the person is diabetic. (Figure 4.4.3)
Figure(4.4.3) Predictive System

Making a Predictive System

```
input_data = (5,166,72,19,175,25.8,0.587,51)

# changing the input_data to numpy array
input_data_as_numpy_array = np.asarray(input_data)

# reshape the array as we are predicting for one instance
input_data_reshaped = input_data_as_numpy_array.reshape(1,-1)

# standardize the input data
std_data = scaler.transform(input_data_reshaped)
print(std_data)

prediction = classifier.predict(std_data)
print(prediction)

if (prediction[0] == 0):
  print('The person is not diabetic')
else:
  print('The person is diabetic')
```

```
[[ 0.3429808   1.41167241  0.14964075 -0.09637905  0.82661621 -0.78595734
   0.34768723  1.51108316]]
[1]
The person is diabetic
```

Thus, the big data being generated by IoMT-medical devices or medical applications, if collected, cleaned, standardized and structured properly, can be utilized for Healthcare Predictive Analytics. There would be different data points for predicting different chronic diseases. To obtain and preprocess this information, it is imperative that we identify the specific data points. When chronic diseases are diagnosed early, patients have a better chance of managing the conditions and preventing or delaying serious complications that can diminish their quality of life. Thus, IoMT may play a major role in improving quality of care and overall population health.

4.4. Challenges of IoMT and Solutions

In order to address various concerns related to the “application of IoMT and related technologies for healthcare, a lot of research is being carried out. It is still necessary to deal with many open challenges. A number of notable challenges are discussed in this section, along with their solutions in the existing literature. These include fault tolerance, latency, energy efficiency, interoperability, and availability”(20)

Fault Tolerance:

“Sensors and communication nodes that transfer data to the cloud or a processing layer determine the reliability of an IoT healthcare system. During an emergency, their functioning is crucial to ensuring that medical services are reliable and credible. As far as we know, the only possible solution for fault tolerance in the existing literature is an IoT architecture (46) that uses backup nodes for communication failures” (46,47)

Latency

“Network latency at the transport layer and the communication layer are crucial for the efficiency of healthcare applications. In addition, the impact of latency depends on the type of healthcare application”(47). Especially in healthcare applications such as live surgeries and emergency services, latency is a defining factor. “IoT architectures with fog-based data preprocessing at the gateway instead of sending data to the cloud, which introduces more latency, have been proposed”(48).

Energy efficiency

“Sensors at the perception layer are more or less powered by batteries. Battery depletion results in the shutdown of sensor nodes, which are essential to the functioning of the system in emergency healthcare applications” (30). “Solar-powered WBAN nodes have been proposed as an alternative to battery-powered nodes for healthcare” (35). Using experiments, “maximum solar power was extracted from the panels, and the system functioned 24 hours a day”.

Interoperability

“ As the Internet of Things spans different domains, it encompasses a wide range of disciplines with conflicting standards that pose a problem of interoperability. The problem is Regulations and standards in the healthcare industry impose stringent requirements on compliance” (33). “Using 6LoWPAN, an open standard built on top of IEEE 802.15.4, a real-time health monitoring system was proposed that addresses the issue of interoperability among communicating nodes” (35). “In addition to abstracting the complexity of the details through middleware, another approach to solving the interoperability issues has been suggested” (8). “To address the challenges between heterogeneous devices in the IoT infrastructure, a semantic interoperability model has been proposed. For associating the things and querying them for extracting information, this model uses Resource Description Framework (RDF) and SPARQL”(36).

“The patient's data should be available 24/7 in IoT healthcare applications like real-time monitoring and emergency care services to allow physicians to take appropriate measures” (20). “The non-availability of vital data that is required for treatment causes the death of a patient when nodes are unavailable or networks are down. With VICINITY, a European Union (EU) funded project, the communication load can be scaled up and down based on the requirements”(16). “Cloud computing, big data, etc. are some of the technologies at the processing layer that need further research. An IoT healthcare system should be made highly available, which can be accomplished by mitigating the risks and vulnerabilities associated with cloud computing” (17)

Chapter 5-Recommendations

“The healthcare sector is abuzz with talk about the potential of the Internet of Things (IoT). In clinical settings, devices and sensors are already deeply embedded, and consumers are more connected than ever, and very comfortable using health and activity monitors. A wealth of rich data is resulting as a result, which can deliver benefits in terms of empowering patients, reducing costs, and improving patient care.”

“The process isn't as straightforward as it seems. It is also true that an industry struggles to overcome the obstacles it faces in adopting and realizing the benefits of digital technology. Its long-entrenched political and governance structures are impeding progress, and it has a long way to go.” (40)

Managing health issues, especially chronic diseases are becoming a serious challenge for healthcare systems due to an aging population with chronic diseases and an insufficient supply of health care services. So, the world healthcare system needs a transformation from a clinic-centric environment to a personalized, information-aligned environment. (35)

By utilizing IoT technologies, modern healthcare can connect physicians and patients for automated and efficient monitoring of the daily activities of people of all ages and provide ‘one-stop’ service to people at remote locations by providing continuous monitoring of physiological signals by sensors. In a context where rapid development has occurred in controlling healthcare, this research intends to discuss the latest developments in the field, develop future studies, and assess IoT in healthcare with a standard approach. Additionally, IoT discoveries are disseminating various factors that affect health concerns, which will serve as a starting point for scientists, technocrats, researchers, and the general public throughout this area.

The section will provide some recommendations and opportunities for approaching future trends and data management, compatibility, security, adaptability, and privacy.

Access Control plays a key role in protecting healthcare data and IoT applications. The design of an access control system is critical to the implementation of IoT healthcare devices and applications. IoT devices can send health data to healthcare databases.

Access management is essential for IoT healthcare applications to ensure data security and privacy. In order to protect crucial data and to control data access, access control systems may be used by organizations.

Employers in the healthcare industry need to be aware of information security in order to ensure the security of IoT applications and secure patient data. Information security awareness training should be provided to healthcare workers. The company should provide employees with a benefits package all For the protection of data, privacy, and the rights of patients, access control training is of prime importance.

By implementing access management, IoT healthcare applications can prevent misuse of healthcare data and malicious attacks against the users' health data. Small and integrated, Internet of Things health devices are becoming increasingly popular. Data is collected from various environments by IoT health devices. Therefore, IoT health devices must ensure physical security. Physical threats should not be posed to IoT health devices (Shen and Liu, 2011). Health data and IoT devices are protected against environmental threats, accidents, theft, and physical sabotage. Devices that connect to the Internet of Things should be protected against physical attacks.

So, IoT health devices continuously collect and send data. The damage from attacks, accidents, and disasters should be decreased by taking measures to reduce the damage. Devices and applications that rely on the Internet of Things need to be secured. In the Internet of Things, device communication is done through a network.

The development, documentation, and implementation of policies, guidelines, and standards can be undertaken. Additionally, international organizations publish a number of standards concerning healthcare security. Providing security and privacy is the reason for using these documents.

Data security and privacy should be well-documented among employees and departments. Regular reviews and updates of the policies could take place, and they can change as the healthcare sector changes. In order to improve healthcare workers' understanding of information security, training should be prepared.

Trainings on IoT security and privacy are provided by these trainings, which emphasize the importance of privacy of health data recommend providing these trainings on a regular basis to employees.

A central log management system should be used to gather log information from devices, applications, and components of IoT healthcare systems. In order to prevent unwanted events in healthcare systems, logs are monitored, analyzed, and evaluated. Auditing SIEM (security information and event management) is another important step. Security team members need to be notified quickly of unwanted events to prevent them. Authentication and authorization should be strong on a central log management system (log management or SIEM) in order to monitor audit logs. Continually checking the log is recommended. As a passive defense, auditing is made possible by becoming aware of critical security events after they occur. Auditing helps people respond quickly to unwelcome events.

Another issue hindering the growth of connected health is the flood of data. Even though the volume of data collected has increased exponentially, the value of this data has yet to match its volume. Data collection and transmission by themselves do not improve outcomes. Snake oil is one way of describing this issue concisely.

It is not the best use of anyone's time to require healthcare professionals to carve out time to review data, which may not be of use to patients or clinicians. Data is most valuable when it provides healthcare professionals with actionable insights.

In an ideal connected health system, problems will be identified, and instructions will be provided about how to handle them. Rather than spending time determining what the appropriate treatment pathway should be, the physician can focus on administering the appropriate intervention. In order for this to happen, solutions, data review protocols, triage, and interventions need to be developed in collaboration with clinical stakeholders.

The connected health monitoring protocols can be developed sufficiently to provide a discrete response and avoid the need for clinical interpretation if they focus on specific issues with clear definitions. An AI instead of a medical professional may conduct the review in such cases.

Indemnity

To enable widespread adoption of connected health solutions, the traditional fee-for-service payment model must be overcome. There is a gap between connected health solutions that focus on prevention, and the payment models that pay for services.

Therefore, it becomes increasingly important to demonstrate the effectiveness and economic benefit in order to make a strong case for reimbursement. Pilot studies with partner organizations are necessary before connected health solutions can be proven to be effective in the real world. It is possible that traditional clinical trials are less valuable than a therapeutic product. This is because one of the main concerns about connected health solutions is adherence in the real world, which is a challenge to answer with an RCT.

Consequently, a study should measure and define measurable clinical and economic outcomes of the solution. Studies done in collaboration with a company may have a greater impact on adoption than those conducted on their own.

User Experience Design

Recently, the FDA updated its guidance on human factors and usability engineering for medical devices. This guidance is primarily focused on minimizing patient risk. The methodologies recommended can be adapted to improve the design of a product for all stakeholders by applying them to other aspects of the product lifecycle.

Rather than focusing on how the patient uses the device, most user interface design focuses on the steps where the product will be used; prescription and payment, training and set up, actual use by the patient, review, and intervention.

Thus, the main drivers that will overcome the issues concerned with adoption of IoMT can be summarized below: (Figure 4.1)

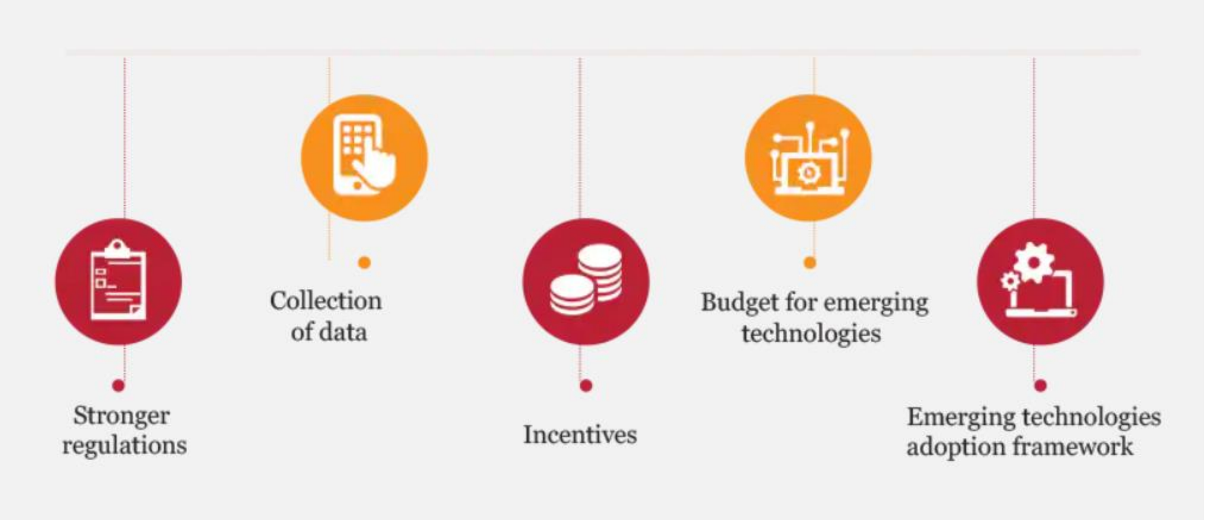


Figure 4.1. Drivers for change (49)

In addition to improving outcomes and reducing costs, connected health offers huge potential. All stakeholders, however, will have to lend their support to the transition to a new model of care. It is thus crucial to focus mid-term on devising and implementing solutions that consider all lifecycle elements as well as having outstanding data to demonstrate their efficacy and cost effectiveness. Connected health can be widely adopted if certain specific issues can be resolved.(49)

Chapter 6-Conclusion

Healthcare industry is rightly riding the wave of change as the Internet of Things (IoT) emerges as the next big wave of the industrial revolution. Innovative medical devices, medicines, patient monitoring, and much more are being developed rapidly, and healthcare practitioners worldwide are closely watching the development to see how the Internet of Medical Things (IoMT) will impact them.

A medical IoMT consists of a connected system of medical devices and applications that collect data and transmit it to healthcare information systems via online computer networks. Implementing smart technology in the healthcare industry could, in fact, lead to lifesaving efficiency and accuracy.(2,16,20)

IoTization - Going Beyond Traditional Healthcare

Health executives in India have invested more in IoMT in the last decade than in the previous decade because they believe technology will help create a well-connected healthcare ecosystem.

Prior to IoMT, a patient's contact with a doctor was limited to physical visits, teleconferences, or texts. Medical representatives continually faced challenges in monitoring a patient's health. IoMT healthcare has made remote monitoring feasible using mobile devices, apps, wearables, and sensors. Additionally, it has unlocked the potential for keeping patients safe and healthy, as well as making physicians more capable of providing excellent remote and personal care.

Implementing smart technology in the healthcare industry could, in fact, lead to lifesaving efficiency and accuracy. The Internet of Things has undoubtedly revolutionized the healthcare industry by reimagining the way devices and people interact in providing healthcare solutions. The internet of things has applications in healthcare that benefit patients, families, doctors, and hospitals.(6)

IoMT can play a huge role in preventing and predicting diseases, which is perhaps its most profound impact. It serves to reduce the number of hospitalizations while improving the quality of care and allocating resources to the most critical areas.

Healthcare is rapidly undergoing a digital transformation thanks to the IoMT. In addition, it is redefining people's interactions with devices and delivering healthcare services. The adoption of IoMT in healthcare benefits patients, families, doctors, hospitals, and insurance companies.

It decreases costs for doctors and hospitals through real-time access to patient data and improves workflows through sensor-based smart chips and real-time location systems. This results in lower claim payments for health insurance companies. It allows pharmaceutical companies to communicate. By early detecting illnesses, we can begin medications on time and ensure compliance with treatment. Additionally, it monitors and sustains the health of a population for a government.(6,7,18)

It seems that IoMT could be of use to Indian healthcare, but there are a few bottlenecks to its adoption. Health care is forecast to generate more data than any other industry by 2025. It is possible that healthcare organizations may experience unexpected issues as a result of the flood of data created by IoMT devices and equipment. Healthcare systems must be scaleable and robust in order to handle the voluminous data they generate.

With the adoption of devices rising, so too do hackers' ways of infiltrating and stealing data from vulnerable systems. In order to combat this problem, the industry needs to raise awareness of current threats and understand how to protect networks from hackers. The upgrade could also be hampered by outdated infrastructure and a lack of technical talent.

The lack of standardization of processes is also hampering the adoption of IoMT by the industry. Despite acknowledging the challenges, debates frequently revolve around the methods of meeting them. The treatment process differs greatly by hospital, and even by doctor, and there is little agreement with regard to how it should be done.

Health Care in India: An Evolving Landscape

Consumers in India are more vigilant and demanding than ever before. In response to this, the demand for cost-effective healthcare has increased, telemedicine has emerged, health insurance companies have penetrated, and various Government schemes have come into play.

Indian healthcare will need to reanalyze the future with evolving technologies, while striking a delicate balance between:

1. Increasing expectations of care for patients in a connected ecology and the facelessness of technology-driven healthcare

2. Increasing costs and limited budgets in healthcare

3. New technologies are complex and difficult to deploy, integrate, and secure. (10)

This is an essential part of an ongoing information security program that can help organizations to leverage the benefits of increased interconnectivity as dictated by ROI, while minimizing the very real risks associated with IoT. (8) To counter potential security threats of IoT until the regulations are made, healthcare enterprises will need to take the necessary precautions and put proper security measures in place. Healthcare will find endless opportunities for innovations with the impact of IoT, one thing is certain.

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