Empowering Home Care: Utilizing IoT and Deep Learning for Intelligent Monitoring and Management of Chronic Diseases

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***Abstract*—Integrating Internet of Things (IoT) with Artificial Intelligence (AI) is one of the catalysts for improving traditional healthcare services. This integration has created many opportunities that have led to healthcare shifting towards enabling home care, the concept that harnesses the technologies advanced potential such as the IoT and deep learning for intelligent monitor and manage chronic diseases. As population growth increases, restrictions on traditional healthcare services increase. Some diseases, such as chronic diseases, require innovative solutions that go beyond the boundaries of traditional healthcare settings due to their impact on individuals' health for example traditional healthcare systems have little capacity to provide high-quality and real-time services. Empowering home care services using deep learning and internet of things technology is promising. It enables continuous monitoring through interconnected devices and deep learning, which provides intelligent insights from massive data sets. This brief explores the key components of enabling home care, including continuous patient health monitoring, predictive analytics, medication management, and remote patient support by healthcare providers, and provides friendly interfaces for end-users. The conjunction between the IoT and deep learning in home-care signals a shift toward precision medicine, enhancing patient outcomes and creating a sustainable model for chronic disease management in the era of decentralized healthcare. This review article aims to discuss the following aspects: presenting the latest technologies in home care systems, showing the merit of combining the Internet of Medical Things (IoMT) and deep learning and its role in monitoring patient conditions and managing chronic disease to improve patient health status accurately, in real-time, and cost-effective, and lastly, debating future studies and providing recommendations for the ongoing development of home care remote monitoring applications.**

***Keywords*—IoT; IoMT; intelligent monitoring; chronic diseases; deep learning; home care; physiological data; mHealth**

I. Introduction

In the ever-evolving healthcare landscape, home care has emerged as a pivotal frontier, driven by technological advancements that aim to transform the management of chronic diseases. This paradigm shift is embodied in the concept of empowering home care, where the fusion of IoT and deep learning play central roles in leading a new area of intelligent monitoring and management for chronic conditions. Chronic diseases present substantial challenges to both individuals and healthcare systems, necessitating innovative solutions that provide personalized, continuous, and accessible care. Home healthcare services provide many benefits to the service providers and end-users by allowing service providers to monitor their patients outside the hospital and everywhere with high quality, and they can always connect to their patients. With the entrance of the IoT, the solution of home healthcare becomes proactive by using the term mHealth, which can be defined as "a communication technology integrated with mobile sensors for healthcare" [1]. The number of mHealth applications has increased over the years because of traditional monitoring methods often necessitate frequent visits to healthcare facilities, resulting in inconvenience and escalated healthcare expenses [2]. Moreover, these methods typically involve the use of multiple wearable sensors employing different algorithms, causing discomfort to patients and incurring exorbitant costs. The conventional approach to monitoring chronic diseases involved clinic visits and extracting blood samples from patients at labs. The physician would then evaluate the lab results to determine the patient's status. The disadvantages encompass high costs, prolonged monitoring periods, delayed responses from healthcare providers, potentially leading to patient fatalities, and a surge in the number of patients waiting in clinics [3], [4]. These drawbacks underscore the need for a shift towards real-time patient condition monitoring and exploring alternative methodologies. This review article will discuss three subjects: First, it will discuss recent technology in home care systems. Second, can integrating the IoT and deep learning help monitor, manage, and improve chronic disease patient conditions? Third, recommendations will be provided, and future studies for home healthcare technology will be explored.

A. Background

Due to the high importance of home care in managing and controlling chronic diseases, technology has become a main component of it, such as IoT and deep learning facilitating remote monitoring, management, and controlling the patient condition. Chronic diseases have become one of the specialties that cause significant challenges for healthcare, leading to a shift to decentralized healthcare. Integrating IoT and deep learning plays a significant role in home healthcare. IoT is highlighted as a main technology in home healthcare that allows service providers to perform real-time health patient monitoring through interconnected and wearable devices. Empowering home care leads to providing a holistic and patient-centric approach to chronic disease management, leveraging IoT and deep learning to empower patients, improve health conditions, enhance patient satisfaction, and create a more sus-

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tainable healthcare environment. The author in [5] introduces the potential advantage of using IoT in healthcare to monitor the daily activities of elderly people. The study discusses the heterogeneity and interoperability issues related to disregarding healthcare for IoT. This study proposed H3IoT architecture to support home care for the health monitoring of elderly people, focusing on its ease of use, mobility, and cost-effectiveness. The H3IoT can provide support in many aspects, such as protective and monitoring health care, and chronic disease management. The author in [6] explores the potential of using IoT and big data analytics for chronic disease monitoring in Saudi Arabia, with a specific focus on hypertension. It aims to develop a predictive system for detecting and managing chronic diseases by presenting a framework consisting of four modules: data collection, storage, processing, and analysis. Decision Tree (C4.5) and Support Vector Machine (SVM) models were employed to predict hypertension, identifying age and diabetes as significant contributing factors. The accuracy of the Support Vector Machine algorithm is 71.15%, while the accuracy of the C4.5 algorithm is 68.80%, highlighting the predictive capabilities of these models. The authors emphasize the transformative potential of IoT and big data analytics in enabling the early detection of chronic diseases and enhancing healthcare services in Saudi Arabia. The research concludes that while the proposed models are effective for disease prediction, further refinement and evaluation are necessary to optimize their performance. Ultimately, this review underscores the revolutionary impact of IoT and big data analytics in chronic disease monitoring and healthcare innovation. The author in [7] investigates the application of machine learning (ML) techniques to analyze chronic diseases using diagnosis codes from the CMS dataset. Focusing on clinical and claims data for 11 chronic diseases, the study aims to reduce the set of diagnosis codes and assess their relevance to healthcare decision-making. The experimental setup involves restructuring the data, applying attribute reduction techniques, and utilizing classification algorithms to derive insights. The study demonstrates that the reduced set of diagnosis codes provides valuable insights for informed healthcare decisions. For the training data, most of the 11 chronic diseases achieve an accuracy above 88%, with stroke and chronic kidney disease showing the highest accuracy. For the testing data, the accuracy for most chronic diseases ranges between 80-90%, with cancer and stroke achieving accuracies above 90%. In contrast, chronic heart failure and depression exhibit lower accuracies of 79.15% and 77.02%, respectively. These findings highlight the effectiveness of ML techniques in analyzing chronic diseases and their potential to support healthcare decision-making. The author in [8] discuss that healthcare landscape is rapidly evolving, with an increasing emphasis on delivering high-quality care within the comfort of patients' homes. This shift toward home-based care is driven by an aging population and the growing demand for patient-centered solutions. At the forefront of this transformation is the powerful synergy between the Internet of Things (IoT) and deep learning. IoT, with its network of interconnected devices and sensors, facilitates the real-time collection of data on various aspects of a patient's well-being. Deep learning, a subset of artificial intelligence, excels at extracting complex patterns from vast datasets, making it a critical tool in modern healthcare.

By applying deep learning algorithms to the extensive data collected by IoT devices, healthcare providers can unlock numerous benefits, including improved diagnostic accuracy and personalized care. For example, studies have demonstrated that for training data, most of the 11 chronic diseases analyzed achieve an accuracy above 88%, with stroke and chronic kidney disease showing the highest performance. For testing data, the accuracy for most chronic diseases ranges between 80% and 90%, with cancer and stroke achieving accuracies above 90%. However, chronic heart failure and depression exhibit lower accuracies of 79.15% and 77.02%, respectively. These lower accuracies are attributed to the variability in diagnostic tests for these conditions. This highlights the need for further advancements in data collection and analysis to ensure consistent accuracy across all conditions.

The author in [9] discusses the landscape of healthcare growth where emphasis on providing patient-centered care that is both effective and affordable. Within this landscape, home care emerges as a critical component, allowing individuals to receive care in familiar surroundings. The convergence of the IoT and deep learning presents a transformative opportunity to revolutionize home care, enhancing both the quality of care and the efficiency of service delivery. This study explores the application of Multi-Step Deep Q Learning Network for securing healthcare data within the IoT framework. This convergence of deep learning and IoT immense to transform home care, making it more proactive, personalized, and effective. The author in [10] discusses the prediction of heart disease using an IoT-based ThingSpeak framework and a deep learning approach, proposing a system that leverages IoT technology and deep learning to achieve real-time predictions. The integration of IoT sensors with advanced deep learning models enables the continuous monitoring and analysis of patient health data, providing early warnings and facilitating timely interventions. This approach underscores the transformative potential of combining IoT and deep learning in chronic disease management, offering significant improvements in patient health outcomes, reductions in healthcare costs, and enhancements in the overall quality of life for individuals with chronic conditions. The proposed CNN-based heart disease prediction system demonstrated remarkable performance, achieving an accuracy of 98.8% based on experimental results. Additionally, the Matthews Correlation Coefficient for the system was calculated at 0.9321, further validating its reliability and effectiveness. These findings highlight the potential of IoT and deep learning technologies to revolutionize chronic disease management, paving the way for more efficient, patient-centered healthcare solutions.

B. Objectives

The objectives discussed in the current studies are:

- Discuss the current studies that support an overall view of the current state of empowering home care for chronic disease patients and highlighting challenges and opportunities in home care.
- Explore IoT technologies for monitoring and managing chronic diseases in-home care using designed devices and sensors.

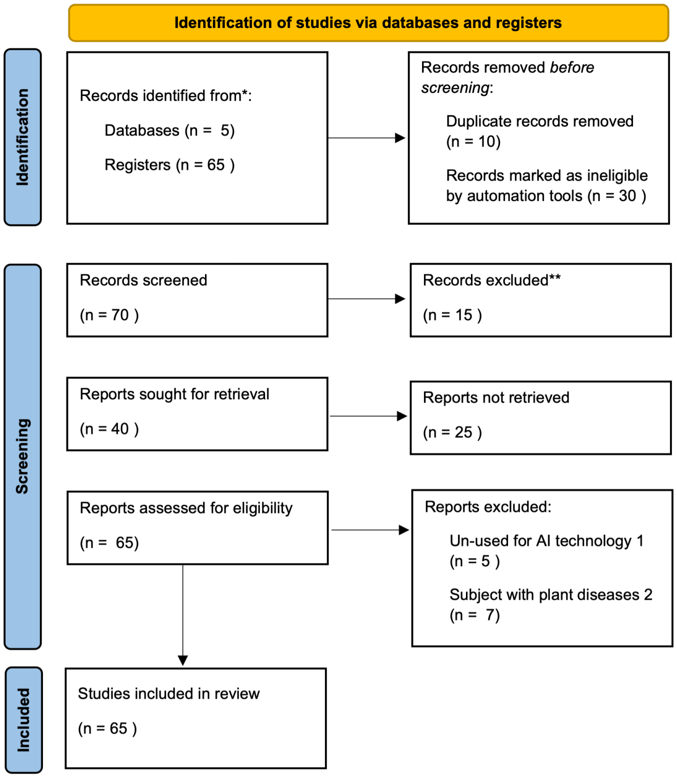

Fig. 1. PRISMA Methodology.

- Evaluate deep learning applications in-home care for intelligent monitoring and management of chronic diseases.
- Identify and analyze the best practices of utilizing deep learning and IoT models to empower home care for chronic diseases.
- Assesses technological challenges and limitations of deep learning and IoT in-home care.
- Provide recommendations and guidelines for activating the positive view of implementing deep learning and IoT and technologies in-home care.

C. Methodology

IoT and deep learning technology have emerged as transformative tools for home care, revolutionizing the way patients are monitored and managed remotely. The main goal of the review article is to find research papers focusing on utilizing IoT and deep learning in-home care and comparing them to achieve the review article's objectives using PRISMA to list of all extracted researches as mentioned in Fig. 1.

This section discusses the methodologies used in the review article as described below:

1) Literature Search Strategy:
Conduct comprehensive literature research using electronic databases, including IEEE Xplore, Google Scholar, Research Gate, and ScienceDirect.
2) Inclusion and Exclusion Criteria:
After filtering the search studies, we included published studies in conference papers, peer-reviewed journals, and literature reviews.
3) Research Summarization: The review article uses two main applications to summarize the research paper: SciSummery to summarize the whole paper and Jenni to find out the technologies used and methodologies.
4) Research Comparison: To achieve a review article's objectives, we used PRISMA in comparing research papers and to find out methodologies used, data collection, IoT sensors, differences, strengths, and weaknesses of research papers.
5) Future and Limitations: Potential limitations of the research papers such as the limitation in methodologies, the chronic disease cases that solution supports, and the accuracy that the research paper reaches.

The rest of this review article is structured as follows: The first section is about IoT in-home care that discusses the integration of IoT technologies in-home care, which revolutionizes health management, offering personalized monitoring and proactive care delivery to enhancing safety and independence. The second section is about deep learning in-home care. It discusses deep learning's vast potential to transform healthcare, particularly in-home care for chronic disease patients, by leveraging advanced algorithms to improve outcomes and reduce costs through remote monitoring and personalized care. The third section is about deep learning in health monitoring. It discusses how deep learning revolutionizes health monitoring and diagnosis, enhancing accuracy and efficiency in disease detection and treatment planning through analysis of vast medical data, improving predictive precision and remote patient monitoring capabilities. The fourth section discusses the intelligent management of chronic diseases. The fifth section discuss benefits and challenges of integrating IoT and deep learning technologies that enhance home care services by enabling interconnected devices to monitor, communicate, and analyze data, creating a safer and more efficient living environment. The sixth section is about the case study using the remote monitoring system of diabetes patients and a case study of predictive analytics for cardiovascular disease management. The last section is the conclusion of this review article. Below Table I is a list of acronyms designed to aid in comprehending technical terms and abbreviations utilized in this comprehensive review. The purpose of this reference table is to assist readers in deciphering the numerous acronyms and their definitions commonly referenced in the exploration of sophisticated topics concerning the IoT, deep learning, and healthcare technologies.

II. IoT in Home Care

In the realm of home care, the combination of IoT technologies is emerge as a transformative force, revolutionizing how individuals manage their health and well-being within the comfort of their homes. IoT-enabled devices, such as wearable health monitors and smart home appliances, provide unprecedented opportunities for remote monitoring, personalized care, and real-time health interventions. By seamlessly collecting and analyzing vital health data, including blood pressure, heart rate, and activity levels, IoT systems provide both patients and caregivers with actionable insights, enabling them to make

TABLE I. NOTATION-TABLE

Acronym	Full Form	Description
ADL	Activities of Daily Living	Tasks related to personal care and routine activities necessary for daily life.
AI	Artificial Intelligence	Simulation of human intelligence processes by machines, especially computers.
COPD	Chronic Obstructive Pulmonary Disease	A group of lung diseases that block airflow and make it difficult to breathe.
EHR	Electronic Health Record	Digital version of a patient's paper chart containing medical and treatment history.
IoT	Internet of Things	Network of physical devices embedded with sensors and software to exchange data.
ML	Machine Learning	A branch of AI focused on building systems that learn from data to make predictions or decisions.
SVM	Support Vector Machine	A supervised machine learning algorithm used for classification and regression analysis.
WHO	World Health Organization	A specialized agency of the United Nations responsible for international public health.
CNN	Convolution Neural Network	Type of deep learning algorithm specifically designed for processing structured grid data.
SSO	Sparrow Search Optimization	A nature-inspired optimization algorithm based on the foraging behavior of sparrows, used to solve complex optimization problems.
SSO	Salp Swarm Optimization	A bio-inspired optimization algorithm modeled after the swarming behavior of salp chains in the ocean, used for solving complex optimization problems.
VAE	Variational Autoencoder	A type of generative model in machine learning that learns to encode input data into a latent space and then decode it back, allowing for the generation of new, similar data.
ECG	Electrocardiogram	A medical test that records the electrical activity of the heart over a period of time.

TABLE II. IoT SENSORS UTILIZED IN THE RELATED LITERATURE

Ref. No.	Sensors
[5]	Acceleration sensor Motion sensor mathElectroencephalogram (EEG), Electromyogram (EMG)
[12]	Camera Sensor
[13]	accelerometers and gyroscopes sensors , environmental sensors
[14]	accelerometers Sensor gyroscopes Sensor Push button 5 MP camera, voice reminder Jetson TX2
[15]	Temperature sensors Heart rate sensors
[16]	wearable sensor
[17]	Temperature sensors Blood pressure sensors Heart rate monitors Glucose level sensors Oximeters Accelerometers Gyroscopes ECG sensors EEG sensors Respiratory rate sensors Humidity sensors Wearable fitness trackers
[6]	Temperature sensors Blood pressure sensors Heart rate monitors Oxygen level sensors Glucose level sensors Respiratory sensors Electrocardiogram monitors Electroencephalogram sensors Motion sensors Wearable fitness trackers Sleep pattern monitors
[18]	smart wristband
[7]	Nan
[19]	Temperature - Blood pressure Blood pressure
[20]	Temperature Blood Humidity Light intensity Soil moisture
[10]	Heart rate Blood pressure ECG Oxygen saturation Temperature

informed decisions about health management and treatment adherence.

As the IoT ecosystem continues to evolve, fueled by advancements in IoT devices technology, data sciences, and connectivity infrastructure, its power to revolutionize home care delivery and promote independent living for individuals of all ages remains unparalleled. Furthermore, the integration of IoT in healthcare research provides vast datasets that lead to enhance patient outcomes and innovative strategies to meet individual patient needs. Overall, IoT technology fosters a more responsive, personalized, and cost-effective healthcare ecosystem [11]. This section will present IoT-enabled devices, data collection and integration, remote monitoring, alert systems, and deep learning for health monitoring.

A. IoT-Enabled Devices

This section will present IoT sensors utilized by research papers in chronic diseases. The below Table II presents sensors used with their definitions:

B. Data Collection and Integration

This section will demonstrate the data collection used to monitor and predict chronic diseases.

The author in [5] discusses that data collection is a broader context for healthcare. It suggests that data collection is happening through traditional channels such as hospitals, community healthcare settings, and public health organizations, but also increasingly through new methods like wearable devices and social media analytics. The adoption of Electronic Health Records (EHR) has been instrumental in improving data collection and consistency. The paper also mentions challenges related to the storage and access of large volumes of data and the need for a concerted effort to enable various professionals to access these datasets.

The author in [6] discusses the methodology used in data collection and integration in the form of utilizing IoT sensors in health care. It typically involves several steps, including

Data Collection: This involves using sensors and IoT devices to collect various types of health-related data, such as vital signs (temperature, heart rate, blood pressure, etc.), patient activity, or specific medical parameters.

The author in [7] presents the context of healthcare and especially in studies dealing with diagnosing chronic diseases using ML techniques or integrating IoT technologies into healthcare. Data collection and integration generally go through several steps, starting with data collection and end with feature selection.

The author in [8] discusses the broad strokes of using IoT and deep learning in healthcare. Unfortunately, it doesn't dive into the specifics of data collection and integration methodologies.

The author in [9] emphasizes the critical importance of the security aspects in a healthcare IoT system using deep learning. It does not delve into the specifics of data collection and integration methodologies, as the primary focus is on security. The author assumes data are collected from various devices to processing and analysis in the main server. However, it does not elaborate on the protocols, communication technologies, or data integration techniques employed.

C. Remote Monitoring and Alert Systems

Remote monitoring and alert systems in the medical field represent a significant evolution in healthcare management, leveraging technology to oversee patient health outside of traditional hospital environments. These systems utilize a different of sensors and devices to collect patient information continuously, which is then transmitted to healthcare professionals for analysis and response. The ability to monitor patients in real-time facilitates early detection of potential health issues, enables prompt interventions, and improves the overall chronic diseases conditions, elderly patient care, and post-operative recovery.

Such systems can operate over various networks, including wireless body area networks and personal area networks, and can even employ non-contact methods such as cameras or smart devices, as shown in Fig. 2. This technology not only improves patient outcomes by enabling constant care but also enhances the adequacy of healthcare services by reducing hospital admissions and costs. Medical staff are empowered to focus more on data interpretation and patient care decisions rather than on repetitive monitoring tasks [21].

ML plays a vital role in these systems by analyzing the data collected, recognizing patterns, and predicting outcomes, thus providing pivotal support in decision-making processes. The integration of ML and cloud computing also ensures that massive volumes of medical data are stored and processed effectively, promoting continuous advancements in healthcare delivery.

The author in [5] presents the architecture of H3IoT aims to provide an effective environment for monitoring the health status of elderly people at home, offering advantages such as mobility, affordability, user-friendliness, and tolerance for delays in data transmission. The system would also include an alert mechanism which automatically sends notifications to designated individuals or emergency services if the data indicates a cause for concern, such as a fall or a serious deviation in health signals. However, the framework may need additional modifications and enhancements to support critical emergency healthcare scenarios.

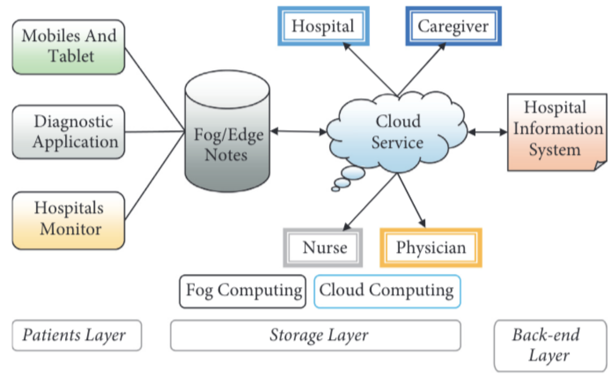

FIGURE 1: General architecture of RPM.

Fig. 2. General architecture of RPM [21].

TABLE III. RESEARCH PAPERS ACHIEVING ARTICLE OBJECTIVES

References	Achieved Objectives
[22] [5] [14] [6] [8] [9] [23] [20] [10]	1- Explore IoT technologies for monitoring and managing chronic diseases in-home care using designed devices and sensors 2- Identify and analyze best practices utilizing IoT and deep learning technologies to empower home care for chronic diseases.
[7]	Does not fulfill the article's objective related to the utilization of IoT sensors

The author in [6] presents a combination of IoT devices for data collection and big data analytics for processing and analyzing the collected data to monitor chronic diseases such as hypertension. The methodology aims to predict and detect health issues, thereby enabling early interventions and improved patient outcomes. After reviewing the IoT sensors utilized in the research papers, it was found that not all studies incorporated IoT sensors in-home care, which does not meet the objectives of this article. Table III illustrates these findings.

III. DEEP LEARNING FOR HEALTH MONITORING

Deep learning has revolutionized the ability to monitor, diagnose, and manage health conditions in the medical field. In the era of digital healthcare transformation, deep learning approaches are applied to parse through massive volumes of medical data.

The introduction of deep learning algorithms into health monitoring systems has significantly improved the precision of predicting patient outcomes and has strengthened the capabilities of remote patient monitoring. By analyzing intricate patterns in data that are often imperceptible to human clinicians, deep learning models can identify potential health issues much earlier than traditional methods, thus aiding in proactive medical interventions.

Additionally, these advanced AI technologies enable personalized medicine, where treatment plans are tailored to the individual characteristics of each patient's condition that leading to better patient health management and can improve patient in home-care. Overall, deep learning in health monitoring stands as a cornerstone in the leap towards more intelligent, responsive, and effective healthcare systems [24].

A. Deep Learning Techniques

The author in [5] presents the architectural concept of H3IoT for home environment monitoring of elderly individuals' health and does not delve into specific deep learning algorithms. Unfortunately, the authors in [6] do not mention the use of a deep learning algorithm for its methodology. But it specifically references the use data mining techniques with the Hadoop framework. For classification and prediction, it cites the use of a decision tree algorithm and SVM algorithm. However, there is another source titled "multi-disease prediction using LSTM recurrent neural (RNN) networks," which does mention the use of a deep learning approach, namely, Long Short-Term Memory RNN, for multi-disease prediction based on patients' clinical records. This approach is distinct from the method used in the first paper and is specifically designed for handling the temporal irregularity across clinical visits and determining the importance of each visit for the prediction task.

Furthermore, the author in [7] does not specify the use of a deep learning algorithm for its research. Instead, it discusses the utilization of ML techniques, such as attribute reduction techniques and classification algorithms, to analyze healthcare data and obtain a reduced set of diagnosis codes for chronic diseases. For deep learning applications within a similar context, the study multi-disease prediction using LSTM and RNN is relevant.

B. Sensor Data Analysis and Processing

Sensor data analysis and processing in the medical field is a crucial aspect of modern healthcare that leverages technology to improve patient outcomes and streamline healthcare services. By introducing IoT, the volume and variety of healthcare data have grown exponentially, presenting both opportunities and challenges. The vast volume of data produced by these devices necessitates advanced methods for processing and analysis to derive meaningful insights. Data science plays a pivotal role in this context, providing the tools and techniques necessary for managing, analyzing, and assimilating large quantities of both structured and unstructured healthcare data.

Medical sensor data analysis involves collecting, processing, and interpreting health data generated by these devices to monitor patient health, detect anomalies, and predict health events. This process requires sophisticated algorithms and big data techniques to handle large volumes of structured and unstructured data. The progression of data science and ML has facilitated the development of predictive models that support early disease detection and the customization of treatment plans [25]. Sensor data must be handled with care to ensure accuracy, reliability, and privacy. It involves pre-processing, data cleansing and anonymization, by using secure platforms to store and process data. Data science provides managements tools to manage patients health status data to extract meaningful information, which can be used in making important decisions about patient care. Effective data management and analysis can yield factual results crucial for proactive health monitoring, specific treatment plans, and instantly detecting of potential health issues. The process typically involves data cleansing, data mining, preparation, and analysis. Successfully integrating sensor data analysis and processing in healthcare can lead to groundbreaking advancements for patient monitoring remotely that lead to improve chronic disease management. The sensor data analysis and processing mentioned by the author in [5] could include several steps:

- Data Cleaning and Pre-processing
- Data Integration
- Real-Time Monitoring
- Pattern Recognition
- Predictive Analysis

If the study includes an IoT framework for health monitoring, it is likely that any or all of these data analysis and processing techniques could be employed within that framework.

Data analysis and processing, as proposed by the author in [6], are achieved through a integration of big data technologies and ML algorithms, specifically:

- Big Data Processing
- Data Storage and Management
- Data Analysis Integration

The purpose of these techniques is to process and analyze the collected data so that predictive models can be developed and applied, which are then able to identify potential cases of hypertension and possibly other chronic diseases in the data set. These models serve as a framework for early detection and ongoing monitoring of patient health, which could lead to better management and treatment outcomes.

Furthermore, the sensor data analysis and processing mentioned by the author in [7] focuses on the analysis and processing of clinical and claims data to study 11 chronic diseases. While the specific details of the data analysis and processing steps are not provided in the excerpts.

C. Disease Prediction and Risk Assessment

The use of IoT and AI in disease prediction represents a significant advancement in healthcare.

This data can include heart rate, blood pressure, glucose levels, and more, depending on the sensors' capabilities. AI comes into play by analyzing this massive stream of data to identify patterns and anomalies that might be indicative of health issues. Techniques from AI, like ML and deep learning models trained using vast datasets to learn from past examples. This training allows AI systems to predict potential diseases or health risks before they become critical, offering a chance for early intervention [26]. IoT provides the real-time data that AI models require to be accurate and effective, while AI gives the tools to make sense of the IoT-collected data, providing

TABLE IV. RESEARCH PAPERS ACHIEVING ARTICLE OBJECTIVES IN DEEP LEARNING

References	Achieved Objectives
[5]	1- Evaluate deep learning applications in-home care for intelligent monitoring and management of chronic diseases
[8] [9] [10]	2- Identify and analyze best practices utilizing IoT and deep learning technologies to empower home care for chronic diseases.
[6] [7]	Does not fulfill the article's objective related to the utilization of deep learning algorithms

insights that healthcare professionals can use to diagnose and treat patients more effectively. The integration of IoT and AI in healthcare has the potential to transform patient care by improving disease prediction, enhancing remote monitoring, and personalizing treatment plans.

The disease prediction and risk assessment presents by the author in [6] is achieved by developing a framework that utilizes decision tree and SVM techniques. The goal is to predict hypertension by analyzing health data collected from IoT devices.

The disease prediction and risk assessment presents by the author in [7] discusses by the following steps:

- Data Collection: Collecting patient data which may include demographics, clinical history, lab results, medication, etc.
- Data Preprocessing: Cleaning and structuring the data to be suitable for machine learning models.
- Feature Selection: Determining which data points (or "features") are most relevant to predicting a specific disease or risk level.
- Model Development: Using statistical or ML algorithms to create a model that can predict disease likelihood or risk based on the features.
- Validation and Testing: Testing the model against a dataset that was not used during the training to evaluate its performance and accuracy.
- Risk Assessment: The model's output may be a probability of disease presence or progression, which can be used to assess risk levels for patients.

At the end of this section, we conclude that not all research papers employed deep learning in home care to monitor chronic diseases. Table IV indicates which research studies meet the article's objectives and which do not.

IV. INTELLIGENT MANAGEMENT OF CHRONIC DISEASES

The intelligent management of chronic diseases involves employing advanced technologies and systems to enhance the care and outcomes for those with long-term health conditions. This approach as shown in Fig. 3, includes the use of personal health systems, connected health solutions, and self-management techniques. These are designed to empower patients to take an active role in managing their own care in partnership with healthcare providers. Through connected health technologies, such as smart biosensors, remote monitoring, and data analytics, patients and health professionals can better track health status and adjust treatments as needed. Digital tools support lifestyle changes, help manage symptoms, and can provide alerts for timely interventions, thus avoiding exacerbations and hospitalizations [27]. Self-management is a complementary concept where patients with chronic illnesses like diabetes, heart disease, and arthritis learn and apply skills to deal with their conditions effectively. This approach includes monitoring symptoms, managing medications, maintaining diet, exercise regimes, and adapting psychologically and socially. The intelligent management of chronic diseases aims to provide personalized care, reduce healthcare costs, and improve the overall quality of life for patients. It represents a strategic shift towards more proactive and patient-centered healthcare models.

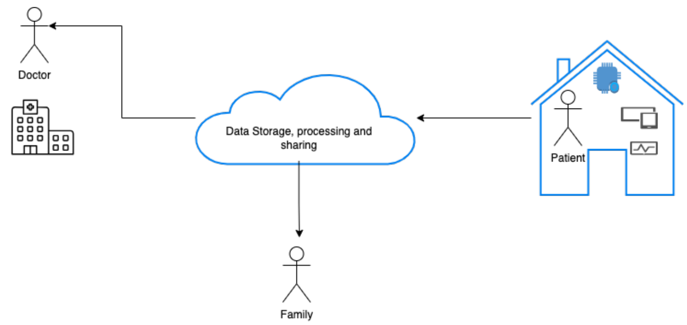

Fig. 3. The health ecosystem.

A. Personalized Treatment Plans

The practice of medicine is evolving, shifting its focus from simply treating disease events to enhancing health, preventing diseases, and personalizing care to meet individual health needs. This transformation is driven by the concept of personalized health care, which utilizes personalized health planning empowered by personalized medicine tools. These tools leverage advances in science and technology to predict health risks, understand disease development dynamics, and tailor therapeutic approaches to individual needs [28]. Personalized medicine plays a crucial role in the management of chronic diseases. By implementing personalized health care and utilizing personalized medicine tools, healthcare providers can create personalized treatment plans for individuals with chronic diseases. These plans are listed to each patient's specific needs, taking into account their genetics, lifestyle factors, and response to previous treatments. This personalized approach in chronic disease management helps optimize patient health status outcomes and enhance the quality of health care.

B. Behavioral Analysis and Intervention

Chronic diseases, such as diabetes, heart disease, and hypertension, are a growing concern worldwide. These conditions require long-term management and intervention to prevent complications and improve the quality of life for patients. Traditional approaches to managing chronic diseases focus primarily on medical interventions, such as medication management and regular check-ups. However, research has shown that behavioral factors play a significant role in the development and progression of chronic diseases [29]. For instance, unhealthy lifestyle choices, such as poor diet, lack of physical activity, smoking, and excessive alcohol consumption, can increase the risk of developing chronic diseases and exacerbate existing conditions. In order to effectively manage chronic diseases, an intelligent approach that incorporates behavioral analysis and intervention is needed. The advanced technologies and data science in healthcare professionals can gather and analyze data on patients' behavior patterns, including their daily routines, dietary habits, exercise habits, medication adherence, and stress levels.

One approach to behavioral intervention is through the use of digital health technologies, such as mobile applications and wearable devices. These tools can provide real-time feedback and reminders to help patients adhere to their medication regimens, track their daily activities, and monitor their progress toward health goals, such as exercise and diet modifications. Integrating behavioral analysis and intervention into the management of chronic diseases has the potential to improve patient outcomes significantly. By addressing the behavioral factors that contribute to chronic diseases, healthcare providers can help patients make positive lifestyle changes and improve their overall health and well-being.

C. Adherence Monitoring and Medication Management

Chronic diseases, like cardiovascular disease, Parkinson's, diabetes, blood pressure, and hypertension, have emerged as major health concerns globally. These diseases have a main impact on the health life quality and can lead to severe complications if not managed properly. According to a study conducted by the Boston Consulting Group (BCG) in 1993, disease management emerged as an innovative approach to improving the quality of care and containing rising healthcare costs associated with chronic diseases [30]. The concept of disease management involves a holistic and integrated approach to patient care, focusing on monitoring adherence to treatment plans and effectively managing medication. This approach aims to optimize patient outcomes by ensuring that patients adhere to their prescribed medications and treatment regimens. One study conducted in Saudi Arabia highlighted the importance of integrating chronic disease management to improve patient care. Another study emphasized the role of big data analytics in improving chronic disease management and healthcare systems. The integration of disease management strategies, such as adherence monitoring and medication management, can greatly improve the management of chronic diseases [6].

V. Benefits and Challenges

The integration of IoT devices and deep learning technologies into home care presents a transformative approach to managing chronic diseases. As the global healthcare landscape shifts towards more patient-centered and technologically advanced solutions, the potential benefits of these innovations are becoming increasingly apparent. IoT devices enable continuous, real-time monitoring of patients, providing valuable data that can be analyzed by deep learning algorithms to offer personalized care, predict complications, and enhance overall health outcomes. This intelligent monitoring and management system promises to improve patient engagement.

However, the implementation of IoT and deep learning in home care also brings significant challenges. These include technological barriers such as integration issues and data security, as well as broader concerns about accessibility, equity, and reliability. Furthermore, ensuring that both patients and hospital providers are adequately trained to use these technologies effectively is crucial. Additionally, regulatory and ethical considerations must be addressed.

In this context, understanding these aspects can guide the development and implementation of more effective and equitable healthcare solutions, ultimately improving the quality of life for chronic disease patients.

A. Benefits of IoT and Deep Learning in Home Care

The integration of the IoT and deep learning technologies showcases the transformative potential for enhancing home care services. IoT in home care refers to the network of interconnected devices capable of monitoring, communicating, and analyzing data to facilitate a more comfortable, efficient, and safe living environment. Deep learning is a subset of AI focusing on sophisticated algorithms that mimic human brain functions, further leverages this data to extract meaningful insights and patterns for improved decision-making and automation. The amalgamation of these two technologies in-home care can lead to the development of smart homes that are not only responsive to the inhabitants' needs but also proactive in maintaining their health and well-being. Smart devices can track vital signs, detect anomalies, and alert caregivers or medical professionals in real time. Deep learning algorithms can process vast quantities of data from various sensors to learn normal behavior patterns and anticipate potential issues, offering not just reactive but preventive solutions for home care challenges [31]. Together, IoT and Deep learning contribute to a more personalized and adaptive home care experience, enabling individuals.

The benefits below collectively contribute to the transformation of home care, making it more intelligent, patient-centric, and efficient through the integration of IoT and deep learning technologies:

- Real-Time Monitoring: IoT devices enable continuous and real-time monitoring of patient's health parameters, providing instant feedback to healthcare providers for timely interventions [32].
- Early Detection of Health Changes: Deep learning algorithms analyze collected data, facilitating the early detection of subtle changes in health conditions, allowing for proactive healthcare measures [33].
- Personalized Care Plans: Deep learning models can process individual health data to create personalized care plans, considering specific patient needs, preferences, and historical health information [34].
- Patient Empowerment and Engagement: Access to personal health data empowers patients, fostering active engagement in their healthcare journey and promoting a sense of responsibility for their well-being [34].
- Cost-Efficiency in Healthcare: By preventing complications through early interventions and minimizing

hospital visits, the implementation of IoT and deep learning can lead to cost savings in the healthcare system [35].

- Data-Driven Decision Making: Deep learning algorithms process vast amounts of patient data to generate meaningful insights, aiding healthcare professionals in making informed and data-driven decisions [35].
- Improved Disease Management: Chronic disease management is enhanced through continuous monitoring, allowing healthcare providers to adjust treatment plans based on real-time data and patient responses [16].
- Scalability and Accessibility: The scalable nature of IoT and deep learning solutions allows for widespread adoption, making advanced healthcare monitoring accessible to a larger population.

B. Ethical and Privacy Concerns

The integration of IoT and deep learning technologies in home care presents transformative opportunities for healthcare, yet it also raises ethical, privacy, and security concerns that require careful consideration. This section explores the key ethical and privacy considerations associated with empowering home care through advanced technologies, emphasizing the importance of safeguarding patient data. Ensuring the security of patient data necessitates the implementation of robust methodologies, including data encryption, secure communication protocols, and multi-factor authentication. These measures protect sensitive information from unauthorized access and cyber threats while maintaining data integrity. Additionally, adopting privacy-by-design principles ensures that security measures are embedded into the technology from the outset, aligning with ethical standards and regulatory compliance. By addressing these challenges holistically, we can build trust and confidence in the use of IoT and deep learning in home care. The author in [36] highlights the ethical considerations related to using deep learning in personalized health monitoring, such as privacy, bias, responsibility and accountability, data quality, and the interpretability of results. In summary, the paper provides valuable insights into the recent developments, challenges, and ethical considerations in the application of deep learning for personalized health monitoring and prediction, underscoring the potential of advanced deep learning algorithms to improve patient outcomes and revolutionize personalized healthcare significantly.

The author in [37] identifies the gaps in the discussion of ethical concerns in both theoretical and empirical research on SHHTs for older persons, highlighting the scarcity of ethical considerations in the field. They noted that while privacy was extensively discussed, other ethical issues, such as responsibility and ageism, were less prevalent in the literature. The review calls for more critical work to prospectively address ethical concerns that may arise with the development and use of new technologies in caregiving for older persons.

The author in [38], discuss the combination of IoT and deep learning offers a powerful toolkit for managing chronic diseases in the comfort of patients' homes. Here are some key benefits for patient, caregivers and for healthcare providers like:

TABLE V. RESEARCH PAPERS ACHIEVING ARTICLE OBJECTIVES, CHALLENGES AND BENEFITS

References	Achieved Objectives
[36] [37] [32]	Assesses technological challenges and limitations of IoT and deep learning in-home care.
[32] [31] [33] [34] [39] [35] [36]	Provide recommendations and guidelines for activating the positive view of implementing IoT and deep learning technologies in-home care.

- Improved Patient Quality of Life: Continuous monitoring and personalized. These insights enforce manage patients, resulting in improved symptom control and an enhanced sense of independence.
- Reduced Burden and Stress for caregiving: Continuous monitoring provides caregivers with peace of mind, knowing that their loved ones are being monitored around the clock. Real-time alerts also allow them to respond quickly to emergencies.
- Enhanced Patient Management for health care provider: Remote monitoring provides healthcare providers with continuous data streams, enabling them to track patients' progress, adjust treatment plans, and intervene proactively.

C. Technical Challenges and Limitations

The technical challenges include data security concerns, interoperability issues, and the need for standardized protocols and regulations to ensure seamless integration with existing healthcare systems and networks [32]. The study addressed the technical challenges and limitations associated with IoT in healthcare systems. Various aspects of end-to-end IoT related to health care were explored. The study discussed the challenges in improving the efficiency of monitoring, such as power absorption and accuracy, particularly in the context of narrowband IoT technology. It was observed that the use of narrowband IoT for high-intensity applications, such as blood pressure and heartbeat monitoring in pregnant women, may support widespread communication with low data cost and minimum processing complexity, yet the limitations of long-range deployment and high latency for critical healthcare applications were identified. The study also presented a detailed review of IoT technologies related to the suggested model, exploring low-power networks and the suitability of IoT-adopted communication standards for healthcare applications. Cloud computing was highlighted as an efficient means of handling and organizing large amounts of healthcare data.

At the end of this section, we identify which research papers focus on the challenges and potential solutions and which emphasize the benefits of integrating IoT and deep learning to achieve the article's objectives, as shown in Table V.

VI. CASE STUDIES AND IMPLEMENTATION EXAMPLES

A. Remote Monitoring of Diabetes Patients

Diabetic Retinopathy is one of the leading causes of blindness among the working-age population and requires early detection for effective treatment. Traditionally, the diagnosis required manual examination by expert physicians, which was time-consuming and not always readily accessible. Diabetes is a chronic disease that requires ongoing monitoring and management. Patients with diabetes and their caregivers face many challenges in managing the disease, such as constantly monitoring blood sugar levels, adhering to medication regimens, and making lifestyle changes. Remote monitoring of diabetes patients is a solution that has emerged to address these challenges and provide better support and care for patients [40]. There have been several studies conducted on the remote monitoring of diabetes patients to assess its effectiveness in improving patient outcomes and quality of life. One study conducted by researchers at Mepco Schlenk Engineering College in India aimed to develop a real-time monitoring system for the vital signs of patients with diabetes using wearable sensors. The study utilized wearable sensors to monitor the vital signs of diabetes patients in real time. The sensors collected data on temperature, respiratory rate, pulse, blood pressure, and blood oxygen saturation. The collected data was stored in a text document and analyzed using data mining approaches. The study found that remote monitoring of vital signs using wearable sensors allowed patients to know their health status without the help of a nurse. Additionally, the study highlighted that remote monitoring of vital signs can help in the early detection of any medical problems or illnesses and alleviate the need for frequent hospital visits. By implementing a remote monitoring system for diabetes patients, healthcare providers can have access to continuous and real-time data on the patient's vital signs. This enables healthcare providers to make informed decisions, adjust medication regimens as needed, and provide timely interventions when necessary [41].

At the end, the use of such technology could lead to a broader application of automated systems in healthcare, helping to prevent loss of vision in diabetic patients.

B. Predictive Analytics for Cardiovascular Disease Management

Heart disease remains a leading cause of mortality globally. Traditional healthcare models struggle with early detection and continuous monitoring of heart conditions, which is crucial for patients at risk of sudden cardiac events. According to a report by the Public Health Foundation (PHF) of India, chronic diseases, including cardiovascular diseases, are the leading cause of death in India. These diseases pose a significant challenge for healthcare systems, specially in monitoring vital signs of chronic diseases patient. Traditionally, the monitoring of vital signs has been done by nurses in hospitals or with the assistance of healthcare professionals at home. However, the advancements in AI technologies and the availability of wearable sensors, real-time monitoring of vital signs has become more accessible. By using wearable sensors, patients can monitor their own vital signs and track their health status without the need for constant assistance from healthcare professionals. This system enables high-risk patients to be checked in a timely manner and enhances the quality of life for patients with chronic diseases. One approach to improve the management of the cardiovascular disease is the use of predictive analytics [42]. Predictive analytics involves the use of data mining techniques to analyze and predict future outcomes based on historical data. By applying predictive analytics to cardiovascular disease management, healthcare providers can gain valuable insights and identify patterns and risk factors that may increase the development or progression of the disease. One study conducted in the United States used survey data and ML models to identify and predict at-risk patients for cardiovascular disease [43].

Further research into incorporating additional deep learning techniques and algorithms into IoT environments promises to improve accuracy and utility for hospitals. Collaboration with more medical institutions to collect extensive data sets would drive the evolution of deep learning models for even better predictive capabilities and treatment outcomes in heart disease management.

VII. Future Directions

The field of healthcare is continuously evolving, and with the advancements in technology, there is a growing opportunity to revolutionize home care for patients with chronic diseases. One future direction for empowering home care is the utilization of IoT and deep learning techniques for intelligent monitoring and management of chronic diseases. By integrating IoT devices, patients can receive continuous monitoring of their vital signs, medication adherence, and overall health status from the comfort of their own homes. This approach has the strength to enhance patient healthcare outcomes by enabling early intervention and personalized treatment plans [44]. Furthermore, the integration of IoT and deep learning in-home care can improve communication and collaboration. Patients and healthcare providers can easily share data and communicate through a secure platform, allowing for timely interventions and adjustments to treatment plans. This future direction of empowering home care through IoT and deep learning has the potential to transform the way chronic diseases are managed and monitored.

A. Integration with Electronic Health Records (EHRs)

The integration of EHRs has revolutionized the healthcare industry by providing a seamless flow of patient information and improving clinical outcomes [45]. However, the future direction of integration with EHRs will focus on further enhancing the capabilities and functionalities of these systems to unlock their full potential in improving patient care and operational efficiency. This will enable a comprehensive view of patient health and facilitate coordinated care across different providers and healthcare settings. With the growth of the populations, healthcare will address challenges related to scaling the system for large populations and ensuring the robustness of deep learning models against noisy, incomplete, or anomalous data inputs from IoT devices. This integration will facilitate personalized medicine and enable proactive interventions to prevent adverse health events and explore the use of federated learning as a collaborative ML approach that allows model training across multiple healthcare entities without sharing raw data, thus preserving patient privacy using the innovative cryptographic methods and privacy-preserving ML techniques [46]. Overall, the future direction of integration with EHRs will focus on leveraging emerging technologies, improving interoperability, and integrating with wearable devices and mobile health applications to enhance patient care.

B. Wearable and Implantable Devices

The field of wearable and implantable devices has seen significant advancements in recent years, with technology becoming smaller, more efficient, and more integrated into our daily lives. These devices offer numerous benefits in healthcare, personal monitoring, and fitness tracking. However, the future of wearable and implantable devices holds even greater possibilities. One future direction of wearable and implantable devices is their integration with AI and ML algorithms. With the advancements in AI and ML algorithms, these devices can not only collect data but also analyze and interpret that data to provide personalized insights and recommendations for the user. For example, wearable devices could utilize ML and provide insights into their stress levels or predict potential cardiac events. Another future direction of wearable and implantable devices is their integration with telemedicine. This integration will allow for remote monitoring and virtual healthcare services. These devices are capable of transmitting real-time data to healthcare providers, enabling them to monitor patients' conditions, intervene in a timely manner, and adjust treatment plans as necessary.

Another future direction of wearable and implantable devices is their integration with IoT technology. By integrating wearable sensors and implantable devices, data sharing across various devices and platforms can enhance the efficiency and accuracy of data collection, analysis, and dissemination, ultimately leading to improved outcomes. The future direction of wearable and implantable devices is focused on the integration of AI and deep learning learning algorithms, telemedicine capabilities, biofeedback therapy, and IoT integration. Some potential future directions for wearable and implantable devices proposed by [47] include, development of advanced ML algorithms for accurate prediction and detection of health conditions based on wearable device data and integration of wearable devices with telemedicine platforms to enable remote monitoring and virtual healthcare services.

These continuously evolving technology platforms not only promise to help people pursue a healthier lifestyle but also provide continuous medical data for actively tracking metabolic status, diagnosis, and treatment. Integration with the IoT is a significant future direction for wearable and implantable devices [48]. The future direction proposed by [49] is revolutionized by the integration of deep learning and IoT with advanced wearable and implantable devices. This will lead to:

- Sophisticated Monitoring: Wearables will go beyond the wrist, using non-invasive methods to track a wider range of health indicators. Smart implantables will enable targeted drug delivery and personalized neuromodulation therapies.
- Data-Driven Insights: Body area networks will connect these devices, feeding data to AI models for real-time analysis, prediction of health events, and personalized recommendations.
- Patient Empowerment: Individuals will receive personalized feedback and use gamified apps to actively participate in their health management.

In conclusion, the future direction of wearable and implantable devices includes integration with the Internet of Things, utilization of AI and ML algorithms, integration with telemedicine platforms, and advancements in monetization and energy efficiency.

C. Collaborative Care and Telemedicine

Collaborative care and telemedicine is very important in healthcare sections. These approaches as proposed by [50]. have shown great potential in enhancing patient care, easy access to all healthcare services, and driving operational efficiencies. Moving forward, there are several future directions that can further advance collaborative care and telemedicine:

- Expansion of Telehealth Services
- Integration of AI
- Remote Patient Monitoring
- Enhanced Communication and Collaboration Tools
- Telemedicine Services Expansion
- Integration with Electronic Health Records

VIII. Conclusion

The integration of IoT technology and deep learning algorithms holds immense promise for transforming the monitoring and management of chronic diseases within home care settings. This convergence represents a beacon of hope, marking the dawn of a new era in chronic disease management. Through the intricate interplay of sensor-laden devices and sophisticated algorithms, we transcend traditional healthcare boundaries, envisioning a future where personalized, proactive, and precise interventions are the bedrock of patient-centric care.

By leveraging connected devices and advanced analytics, providers can deliver tailored, proactive, and efficient care to patients, resulting in improved health outcomes and an enhanced quality of life. However, as we delve deeper into these technologies, it is imperative to prioritize patient privacy, data security, and ethical considerations. Responsible and effective implementation of these innovative solutions in home care necessitates a steadfast commitment to safeguarding patient rights and upholding ethical standards.

Yet, amid the promise of progress, we are confronted with profound ethical and existential questions. As our health data increasingly migrates to the digital realm, we must grapple with the weighty implications of privacy, security, and autonomy. It is essential to strike a balance between innovation and the moral duty to protect patient trust and dignity. Transparency in data usage and robust security frameworks must underpin every technological advancement.

We think, Furthermore, the success of these technologies hinges not only on their development but also on equitable access. It is vital to ensure these advancements do not create disparities in healthcare but instead foster inclusivity by reaching underserved populations. Collaboration between policymakers, healthcare providers, and technologists will be crucial in realizing this vision.

As we navigate this evolving landscape, let us remain vigilant in our pursuit of innovative solutions, mindful of the ethical complexities inherent in healthcare technology. By adopting a holistic approach that prioritizes patients at the center of care, fostering trust, inclusivity, and equity, we can leverage the transformative capabilities of IoT and deep learning to usher in a new era of empowered, accessible, and ethical home care.

ACKNOWLEDGMENT

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Grant No. KFU242729].

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