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Predictive Healthcare and Smart Medical Supply Chains: A Systematic Review of Artificial Intelligence and Machine Learning Techniques

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ABSTRACT

Healthcare informatics has been changed drastically with the rapid development of healthcare data and digital technologies. The data analytics, Artificial Intelligence (AI), and Machine Learning (ML) are relevant to enhancing healthcare decision-making, predicting disease, and operational efficiency. This review examines the use of AI-based data analytics in predictive health care and management of the healthcare supply chain. It notes the adoption of big data, cloud computing, and edge computing technologies and the Internet of Medical Things (IoMT) to assist with intelligent healthcare services. Machine learning models are useful in early disease detection, assessment of the risk in the patient, and planning the treatment. Regardless of such obstacles as data privacy and interoperability, AI has a great potential to improve healthcare delivery and patient outcomes.

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INTRODUCTION

The world healthcare systems are undergoing a digital revolution at a very fast rate due to the increased accessibility of healthcare data and improvement in computational technology. With the advent of healthcare informatics, the systematization of medical data collection, storage, and analysis has become possible to enhance healthcare delivery, patient outcomes, and efficiency. Informatics in healthcare manifests as a combination of information technology, data management, and medical knowledge that helps in making clinical decisions, as well as healthcare administration [1]. Over the past several years, the growing interest in the use of electronic health records (EHRs), wearable health devices, medical imaging systems, and hospital information systems has resulted in the creation of enormous amounts of healthcare data. This information can be used as important information about the disease trends, patient behavior, treatment response, and utilization of healthcare resources when adequately analyzed [2].

The use of data analytics has thus become an important aspect of contemporary healthcare informatics. Healthcare organizations can use such a method to reveal concealed trends, forecast health conditions, and streamline operations by using analytical tools on big data [3]. Predictive analytics, specifically, have received much attention due to its ability to enable the healthcare professional to foresee the possible health problems prior to their escalation. Predictive analytics can be used to predict outbreaks of diseases, predict patient deterioration, and estimate hospital resource needs by means of the statistical models and computational algorithms. This is a proactive strategy that enhances care to patients and saves medical expenses and efficiency in systems [4].

Machine Learning (ML) and Artificial Intelligence (AI) have become relevant and potent technologies, increasing the ability of healthcare data analytics to a significant degree. AI can be defined as computer systems that are meant to carry out functions that are traditionally carried out by human intelligence like learning, reasoning, and decision making [5]. Machine learning, a branch of AI is about the algorithms that can learn historical data and enhance their functionality in the course of time without being coded. The application of these technologies in the field of healthcare has been very common in helping to diagnose medical conditions, predicting diseases, prescribing treatment and monitoring of patients [6]. Restricted learning algorithms like deep learning, neural networks and ensemble models have proven to be very accurate when it comes to analyzing complex medical data, including medical images, genomic data, and clinical records [7].

Predictive healthcare is one of the most promising fields of AI and machine learning applications in healthcare. Predictive healthcare is a data-driven model process that is used to detect possible health threats and predict medical conditions. One of the applications of predictive models is early symptoms

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of chronic diseases, diabetes, cardiovascular disease, and cancer [8]. Seasonal detection will enable the healthcare provider to take preventive measures, which will be beneficial to the patient and reduce the cost of long-term treatment. Moreover, predictive models may help hospitals to control the flow of patients, anticipate hospital readmission, and ensure the optimal distribution of clinical resources [9].

Other than in clinical use, AI and data analytics are also changing the healthcare supply chain management. Healthcare Supply Chain Healthcare supply chain comprises the procurement, storage, distribution, and management of medical supplies, pharmaceuticals, and equipment required in the care of patients [10]. The poor supply chain management may also result in a lack of essential medical supplies, the rising cost of operation, and delay in addressing the patients. Predictive analytics based on AI can assist healthcare organizations in predicting the demand of medical supplies, optimizing their inventory levels, and enhancing the logistics and distribution operations. Predictive analytics can also be significant during the time of global health crises like pandemics to guarantee the timely supply of critical medical provisions [11].

Even though the advantages of AI and machine learning in healthcare informatics are promising, there are a number of challenges still present. Problems with the privacy of data, their quality and interoperability of healthcare systems, and ethical concerns remain the obstacles to the active use of AI technologies in the medical setting. These issues will need a concerted effort on the part of researchers, medical practitioners, policymakers, and technology creators to handle the challenges [12].

This review intends to analyze the prevailing situation of data analytics in healthcare informatics, specifically the uses of artificial intelligence and machine learning to predictive healthcare and healthcare supply chain management. Through the analysis of the current literature and technological trends, this paper attempts to outline the opportunities of AI-based analytics to revolutionize medical systems and pinpoint the most significant gaps in the research to be filled in future studies.

HEALTHCARE INFORMATICS IN DATA ANALYTICS

Healthcare informatics is an interdisciplinary domain that incorporates information technology, data science and healthcare practices to enhance the execution and administration of healthcare services. It is concerned with the effective gathering, storing, retrieving and analyzing medical data to aid in clinical decision-making, healthcare administration and medical research. In the fast process of digitalization of healthcare systems informatics has become an important part of modern healthcare setting [13]. The use of digital platforms in hospitals, clinics, and research institutions is growing, to administer patient records, track clinical activity, and simplify administration. Healthcare informatics

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does not only help to increase accessibility of medical information, but also the accuracy and efficiency of healthcare services [14].

The incredible increase of healthcare data in various sources is one of the major force behind healthcare informatics. These information systems are Electronic Health Records (EHRs), medical imaging systems, laboratory reports, wearable health monitoring systems, and hospital management systems. EHRs also have comprehensive data on patients including medical history, diagnosis, treatment plan, and medication history and laboratory results [15]. On the same note, wearable gadgets and Internet of Things (IoT) technologies capture real time health information by monitor heart rate, physical activity levels and sleep patterns. A combination of these various data sources forms a complete digital health ecosystem with the help of which healthcare providers can gain a clear image of the health of patients [16].

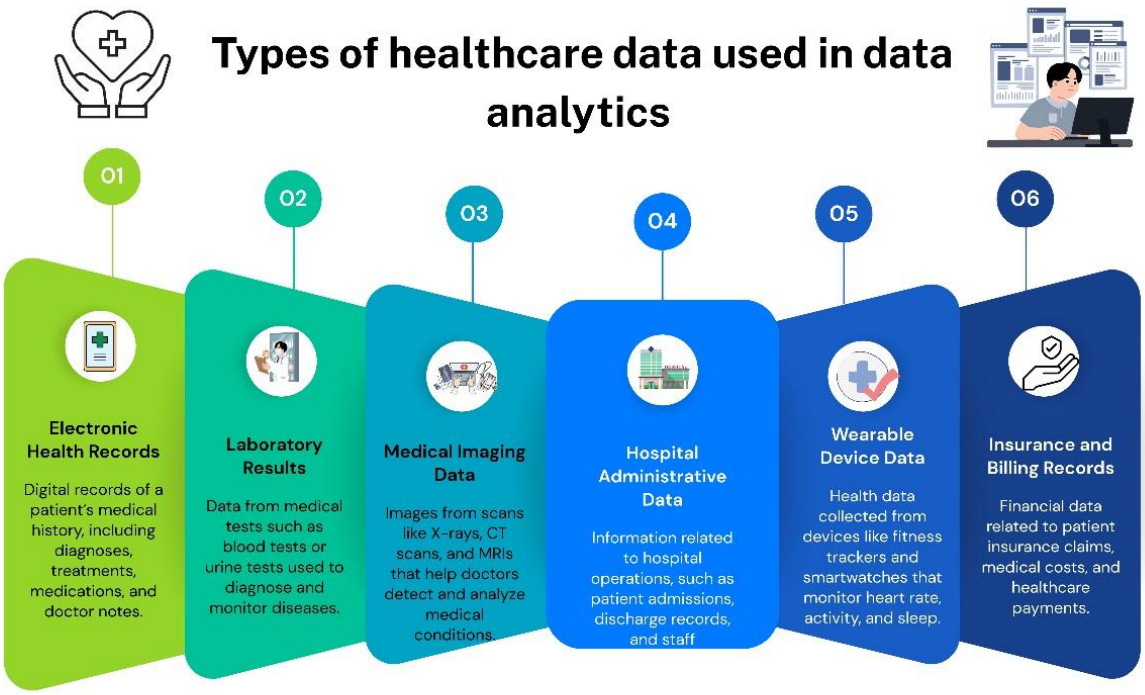

Figure 1. Types of healthcare data used in data analytics

Nevertheless, the sheer amount, data type, and speed of the healthcare information can pose substantial challenges regarding the data management procedures and their analysis. Usually, conventional data processing techniques are not effective enough to work with such complicated data. This is the place where data analytics becomes an important element of healthcare informatics [17]. Data analytics refers to the process of applying statistical methods, computing technologies, and machine learning algorithms to derive meaningful information in raw healthcare data. With the use of the latest analytical techniques, healthcare organizations can convert a massive amount of data into

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meaningful knowledge that can be used in making decisions and providing more effective services to patients [18].

In medical care, there are typically 4 broad classes of data analytics, including descriptive analytics, diagnostic analytics, predictive analytics, and prescriptive analytics. Descriptive analytics is interested in generalizing past healthcare data to know a bit about the past trends and patterns, like the rate of patient admissions or the prevalence of a disease [19]. Diagnostic analytics is further by determining the causal factors of the observed healthcare outcomes. Predictive analytics is based on the interpretation of past data and machine learning models to predict future healthcare events, including the risk of a disease or a hospital readmission. Prescriptive analytics can offer the best recommendations on how to make decisions through the analysis of different possible scenarios and proposing the most appropriate course of actions [20].

The adoption of data analytics into healthcare informatics has greatly enhanced the capacity of the healthcare providers to offer personalized and evidence-based care. As an example, healthcare analytics can be used to locate a high-risk patient and provide an early medical intervention. It may also help clinicians to choose the treatment plans with the highest effectiveness depending on patient information and past medical performance [21]. Moreover, healthcare analytics aids population health management, in that it allows identifying disease patterns in various demographic groups and allows targeting population health activities [22].

Besides clinical value, data analytics also ensures operational efficiency in a healthcare organization. Data-driven insights can help hospitals to optimize resource allocation, minimize waiting times, and manage patient flow better. Indicatively, predictive models can be used to predict the rate of patient admission, thus enabling hospitals to plan better the staff and the available medical resources. In the same way, analytics would be useful in managing inventory, through forecasting the demand of medical supplies and pharmaceuticals [23].

The application of healthcare data analytics encounters various challenges even though it has many benefits. Such concerns as data privacy, data security, data interoperability, and healthcare data format standardization are still critical. Healthcare information is very confidential and requires high adherence to regulations to maintain patient confidentiality [24]. Also, combining data across the healthcare systems may be impractical because of dissimilarities in data framework and technological infrastructures.

The healthcare informatics, together with sophisticated data analysis, offers a strong platform in changing the healthcare delivery. Using data-based understanding, healthcare organizations will be in a position to enhance patient outcomes, operation efficiencies, and contribute to the creation of

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predictive healthcare systems capable of anticipating future healthcare demands and responding to them [25].

CIRCUIT BREAKERS: ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN HEALTHCARE

Machine Learning (ML) and Artificial Intelligence (AI) have turned into revolutionary technologies in the contemporary healthcare. The technologies allow computers and digital systems to process huge amounts of healthcare data and form patterns and facilitate the decision-making process previously relying on human expertise [26]. Application in healthcare informatics AI and ML have greatly enhanced the capability of health care providers to diagnose a disease, predict patient outcomes, and increase the efficiency of healthcare provision.

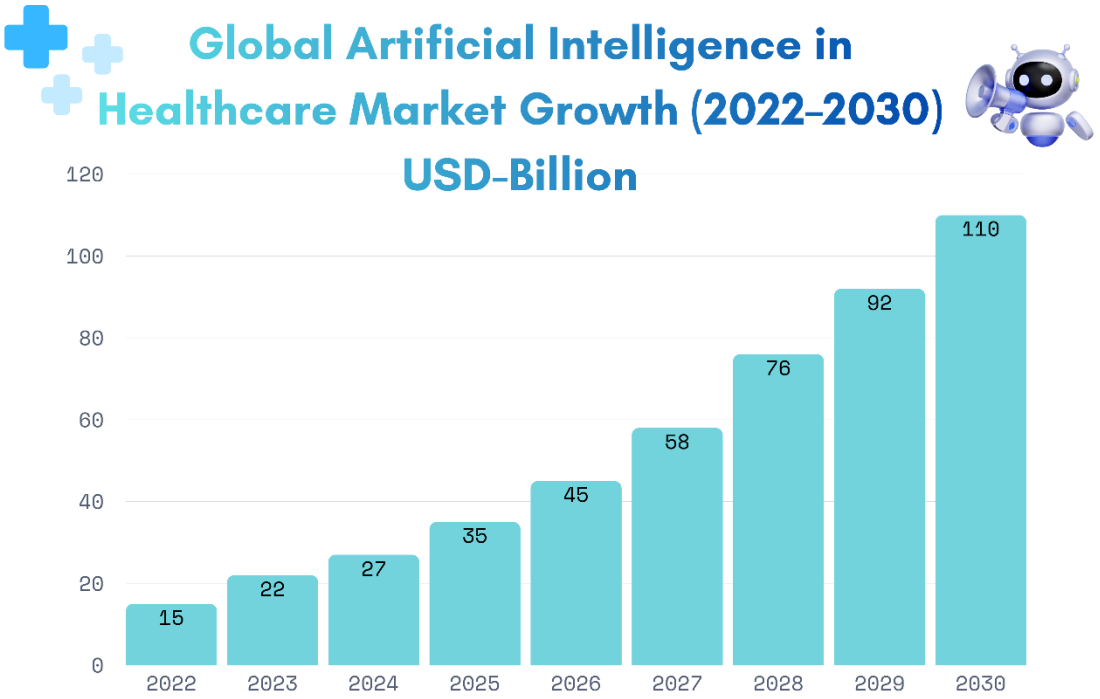

Figure 2. Global AI in healthcare market growth (2022-2030) USD-Billion

Artificial Intelligence can be explained as the creation of computer systems that can perform functions that usually involve intelligence of humans like reasoning, problem solving, learning and decision making. In the medical field, AIs are developed to interpolate complicated medical information and guide clinicians in making correct and prompt medical choices [27]. Machine learning, which is a branch of AI, involves the creation of algorithms that are able to learn based on past information and increase their efficiency through the passage of time without being coded by humans. With the assistance of big data, ML models have the ability to identify latent patterns and make predictions that can assist healthcare practitioners in clinical practice [28].

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The machine learning applied to healthcare can be divided into supervised learning, unsupervised learning, and reinforcement learning. One of the most popular methods of medical data analysis is supervised learning. In this approach, the training of algorithms is made using labeled data sets in which the correct outputs have been known [29]. As an example, one can use supervised learning models that are trained using the medical history of patients to determine whether a specific patient is vulnerable to the occurrence of a disease. The decision trees, support vector machines, logistic regression, and the random forests are common supervised learning algorithms in the healthcare domain [30].

Unsupervised learning on the other hand entails the study of unmarked data in order to determine concealed arrangements or patterns in datasets. The method finds applications in the healthcare field, in segmenting patients, clustering diseases, and detecting anomalies. As an example, unsupervised learning algorithms can cluster patients with similar medical features, which can assist the researcher to identify novel disease subtypes or high-risk groups of patients [30]. Another machine learning methodology is reinforcement learning: this technique aims at training algorithms so that they can make decisions after interpreting the environment and getting feedback as rewards or punishments as a result [31]. Even though it has only recently been utilized in the healthcare domain, reinforcement learning has demonstrated the possibility of being utilized in fields like treatment optimization and personalized medicine where systems learn to prescribe the best treatment plans according to patient response [32].

Deep learning, which is an improved version of machine learning, has been of great interest in the healthcare sector because it is capable of handling extremely complicated information like medical images, genomic data, and speech signals. Artificial neural networks, which are a subset of deep learning models, recreate the human brain structure and are able to process large datasets extremely well. Such models have been effectively used in medical imaging to identify diseases like cancer, tumors and neurological conditions. They are also ideal in processing of radiology images, pathology slides, and other diagnostic data [33].

AI and machine learning in the field of healthcare are associated with various advantages. These technologies enhance the accuracy of diagnostic, minimize human error and allow timely detection of diseases. Intelligent systems that operate with the help of AI can support the work of medical workers, offering them decision support, detecting possible health threats, and prescribing suitable treatment [34]. Also, AI-based analytics may assist hospitals to utilize resources more efficiently, schedule their patients more efficiently, and improve the delivery of healthcare services overall.

Nevertheless, along with their benefits, there are a number of issues associated with the

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implementation of AI and machine learning in healthcare as well. The problems connected with data privacy, transparency of algorithms, ethical dilemma, and regulatory aspects are also a problem. Healthcare information is very sensitive, and patient confidentiality is a key factor to be considered in the implementation of AI-based healthcare systems [35]. In addition, machine learning applications should be critically tested to guarantee the accuracy and objectivity of clinical decision-making. Machine learning and artificial intelligence are some of the most potent resources that are transforming the health sector. They are needed as an independent part of a contemporary healthcare informatics system due to their capability to process complex data, provide predictive insights, and aid clinical decision-making [36].

HEALTHCARE IN PREDICTIVE ANALYTICS

A major use of data analytics in the current healthcare systems has been predictive analytics. It is the application of past medical information, statistical methods, and machine learning algorithms to forecast future health conditions and medical incidents. Predictive analytics is used to analyze trends inside large datasets to help healthcare professionals determine possible health risks, predict development of a disease and take preventive actions before a disease can get out of control [37]. This is a proactive way through which the healthcare services on a patient are enhanced to ensure that there is a reduction in the healthcare expenses as well as the effectiveness of the healthcare systems [38].

With the rapid increase in healthcare data, predictive analytics has been majorly developed. Healthcare organizations are currently able to access enormous volumes of data created on the basis of electronic health reports, medical scans, laboratory findings, wearables, and health monitoring applications. Such datasets are useful in terms of patient health conditions, treatment history, and clinical outcomes [39]. To predict patterns and relationships that cannot be easily identified using the traditional methods of analysis, predictive models are used to analyze these data sources. Disease prediction and early diagnosis is one of the major uses of predictive analytics in healthcare. A patient data can be analyzed using predictive models to determine people who are at a high risk of developing chronic diseases like diabetes, heart disease, cancer, and breathing diseases [40]. The early identification enables the medical caregivers to adopt prevention interventions, prescribe lifestyle change measures as well as early treatment measures. This does not only enhance patient outcomes but also helps to lower the costs of the healthcare systems in the long run [41].

Patient risk prediction is another key predictive analytics use application. Predictive models have been used in hospitals and by other medical professionals in evaluating the risk of complications, disease development or other poor medical occurrences in patients. As an illustration, predictive

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analytics can be useful to determine patients at risk of severe infections, heart failure, and those at risk of intensive care [42]. The healthcare providers can monitor the high-risk patients more closely and give them the required medical care in time by knowing the high-risk patients earlier.

Hospital readmissions are also commonly predicted by using predictive analytics. Hospital readmissions have been a significant issue of concern to healthcare systems due to the rise in the cost of medical care and in most instances, a sign of improper care or follow-up care of patients [43]. Factors that can be analyzed by predictive models include patient demographics, medical history, treatment records and discharge information that can be used to predict whether a patient will be readmitted in a given period. The information will enable healthcare providers to create individual care plans and follow-up plans to minimize readmission possibilities [44].

Besides clinical use, predictive analytics is important in the field of personalized medicine and treatment planning. Predictive modeling can be used to identify the most effective treatment approaches that can be offered to individual patients based on patient-specific data. Such a strategy considers the genetic data, medical history, lifestyle, and reaction to some past therapies. Individualized treatments plans are able to enhance the medical interventions and minimize the danger of adverse side effects [45]. Predictive analytics also helps in enhancing healthcare operations and management. Predictive models can help hospitals predict the rate of patient admission, emergency visits as well as the demand of medical resources. This data assists healthcare administrators in distributing staff and beds and medical equipment more effectively. Moreover, predictive analytics can help in disease outbreak tracking and in planning in the public health by detecting tendencies and forecasting the propagation of the infectious diseases [46].

Although predictive analytics in healthcare have great benefits, some challenges are also associated with it. The quality of the data, the incomplete medical documentation, and the mismatch of healthcare data may also influence the quality of predictive models. Additionally, the issue of data privacy, ethical usage of patient data and the intelligibility of complex machine learning algorithms are the questions of concern that still have to be tackled [47]. Predictive analytics is changing healthcare, as it allows making decisions based on data and proactively treat patients. With the help of sophisticated analytical methods and machine learning algorithms, healthcare organizations can attain better clinical outcomes, increase their levels of operational efficiency and advance to a higher stage of more personalized and preventive healthcare systems [48].

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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IN HEALTHCARE SUPPLY CHAIN MANAGEMENT

Healthcare supply chain management is an important factor that should be utilized to guarantee the supply, distribution and efficiency of the medical resources in the healthcare systems. It encompasses planning, ordering, storage, and provision of medical supplies, pharmaceuticals, equipment, and other fundamental healthcare products that are needed to take care of patients [49]. The effective management of supply chain is the essential factor in ensuring the effective functioning of hospitals and healthcare facilities. Nevertheless, some classic supply chain systems are usually characterized by inaccuracy of demand prediction, shortage of inventory, distribution delays and high operational expenses [50]. Over the past few years, technologies of Artificial Intelligence (AI) and Machine Learning (ML) have been more actively introduced to deal with these issues and enhance the efficiency of healthcare supply chains.

AI and machine learning offer superior analytical functions enabling healthcare organizations to convert extensive amounts of supply chain data and make precise forecasts. These technologies assist healthcare providers in making data driven decisions in procurement, inventory management and logistic planning [51]. The machine learning models will be able to predict the demand of medical supplies more accurately by using the past consumption data, trends of the use of beds by patients, and the demand patterns of the seasons. Demand predictability is accurate, which assist healthcare facilities to have the best inventory level and to prevent shortages of important medical supplies and overstocks [52].

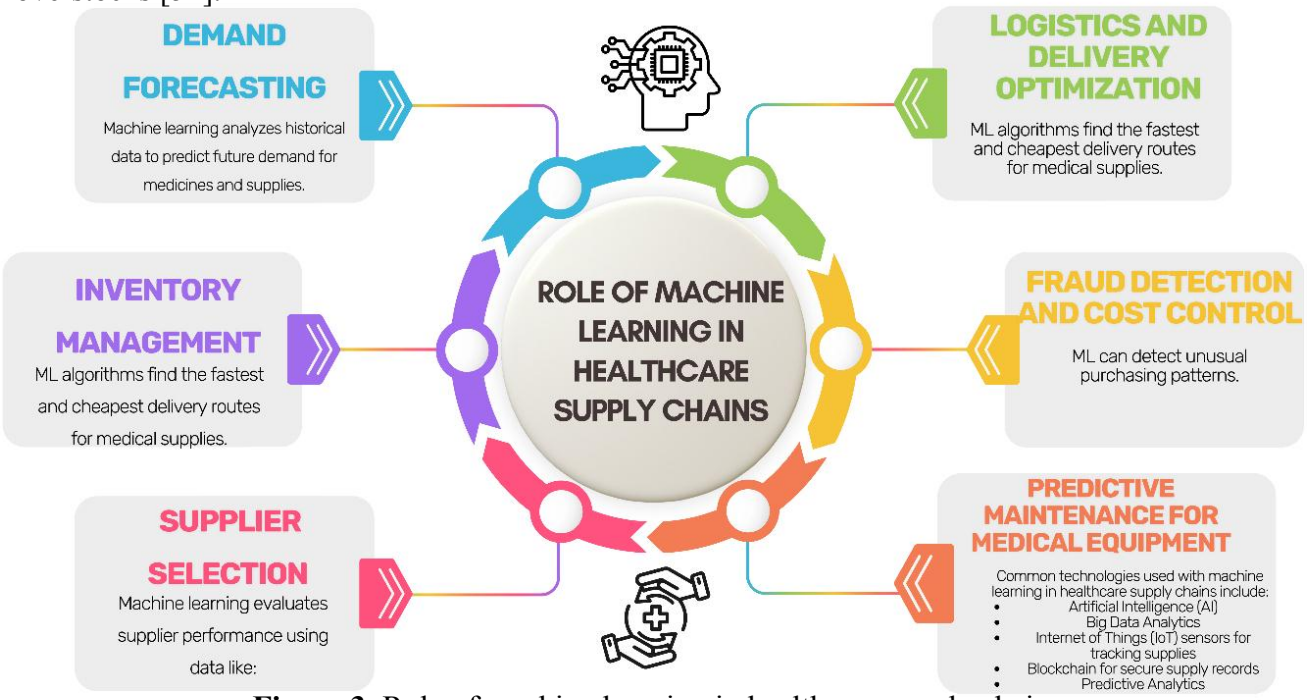

Figure 3. Role of machine learning in healthcare supply chains

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Predictive demand forecasting is one of the most important AI-based health care supply chain applications. There can be a high fluctuation in the demand of healthcare because of outbreaks of diseases, seasonal illnesses, in the growth of the population, and some unforeseen emergencies. The conventional forecasting procedures tend to be poor in adjusting to such changes [53]. Predictive models based on AI have the ability to predict demand more accurately using various data streams, such as hospital data, epidemiological data, and external environmental influences. This helps healthcare organizations to plan ahead and so that medical resources needed will be at the required time [54].

Another field where AI and machine learning have impacted greatly is inventory management. Making sure that the balance between supply and demand is maintained is a significant issue facing healthcare institutions. The surplus level of inventory may result in the waste of perishable medical resources like vaccines and medications whereas the lack of inventory may interfere with patient care [55]. Algorithms of machine learning can be used to track real-time inventory and automatically make suggestions on how to restock or redistribute supplies among the various departments or healthcare facilities. It is a smart inventory control system that enhances efficiency in operations and eliminates avoidable expenses [56].

The AI technologies also facilitate the logistical and distribution operations of the healthcare supply streams. The transportation and distribution of medical supplies is important in ensuring delivery on time especially during emergencies and outbreaks of a disease. Artificial intelligence-based optimization systems have the potential to find the most efficient routes of transportation, shorten the delivery time, and decrease the logistical expenses [57]. Besides, AI has the potential to monitor medical supplies throughout the channel chain, which would ensure transparency and accountability throughout the distribution channels.

There is also another significant impact of AI in healthcare supply chain management, which is the optimization of the distribution of pharmaceuticals and vaccines. The distribution of vaccines and medications in a timely manner during health emergencies like pandemics is a crucial issue in the context of the entire globe. Artificial intelligence systems will be able to process population statistics, patterns of disease spread, and healthcare needs of specific regions and decide on the best distribution strategies. This will make sure that the much needed medical resources will go to the areas where they are required most [58].

Although AI and machine learning present myriads of benefits, there are still a number of obstacles to the implementation of the technologies in healthcare supply chains. Their application can be restricted by issues like data integration, system interoperability, expensive implementation cost, and

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skilled professionals are required. Moreover, health institutions should make sure that AI systems do not violate the regulatory framework and still provide data security [59]. The application of AI and machine learning in the sphere of healthcare supply chain management provides major opportunities to enhance its efficiency, lower its cost, and guarantee the timely access to the necessary medical supplies. Using predictive analytics and smarter decision making systems, healthcare organizations will be able to create more resilient and responsive supply chains that will be able to respond to the changing needs of the modern healthcare systems [60].

AI AND MACHINE LEARNING HEALTHCARE SUPPLY CHAIN MANAGEMENT

Healthcare supply chain management is an important element of healthcare systems that will guarantee the timely delivery and effective distribution of medical supplies, pharmaceutical, equipment as well as other resources necessary to provide care to patients. A functioning supply chain is required to keep the operations of a hospital going, enhance patients outcomes, and cut the operation costs [61]. Nevertheless, the conventional healthcare supply chains are usually involved in issues like incorrect demand forecast, stock shortages, ineffective logistics, and a stand-still between various stakeholders. As digital technologies are developing at a very fast pace, Artificial Intelligence (AI) and Machine Learning (ML) have become potent instruments to make healthcare supply chain management efficient and reliable [62].

Machine learning and artificial intelligence technologies allow healthcare organizations to process high amounts of supply chain data and provide insights that can be used to make more informed decisions. The technologies are capable of handling historical data, patient admission, seasonal disease trends, and other external variables to determine the future demand of medical resources. Predictive analytics also allow healthcare providers to predict the necessity of such medical supplies as medications, surgical equipment, and personal protective equipment with accuracy [63]. This feature is especially valuable in avoiding the lack of essential resources, which may have an adverse impact on the interactions with patients and hospital functioning [64].

Demand forecasting is one of the most important AI applications in the healthcare supply chain. The healthcare demand is extremely dynamic and may vary quickly because of such issues as outbreak of diseases, seasonal illnesses, and emergency cases. Machine learning algorithms are able to interpret data on previous consumption and derive patterns that may be used to predict patterns of demand at future [65]. Such predictive models allow hospitals and other medical organizations to make prior preparations and make sure that they have sufficient stocks once they are required. Proper prediction can also make sure that unnecessary stocks are not piled up and risk of spoiled or wasted medicines is also reduced [66].

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Another significant area that AI and machine learning technologies have proved to be useful is inventory management. Having the best inventory levels in healthcare organizations is important as both surplus inventory and shortages can pose operational issues [67]. Inventory management systems based on AI can keep track of inventory and usage rates to establish when the stock should be replenished. Such systems can be automatically used to generate alerts or restocking recommendations so that healthcare administrators can have an efficient inventory control [68]. The machine learning models can also determine the products with slow movement or high demand thus it is possible to plan and manage the inventory better and also control the cost.

The AI is also significant in maximizing the logistics and distribution process in healthcare supply chains. Medical supplies can only be delivered to hospitals and clinics through efficient transportation and distribution in order to make sure that they get the necessary resources in the right time [69]. The AI-based optimization algorithms have the ability to study transportation routes, delivery schedules, and traffic situations to define the most effective logistics strategies. This aids in minimizing delivery time, minimizing transportation cost, and enhancing the overall excellence of the supply chain activities [70].

This is another important implementation of AI in healthcare supply chain management; pharmaceutical and vaccines distribution. The widespread and effective supply of vaccines and medications is of paramount importance during the times of emergency in the health sector, such as pandemic or outbreak of a disease. Artificial intelligence systems have the ability to analyze information that refers to population demographics, disease distribution patterns, and health care demand levels in a region to then formulate the optimal distribution measures. This makes sure that the necessary medical facilities are availed to the regions where they are most needed. Although AI and machine learning have numerous benefits in healthcare supply chain management, there are still numerous challenges [71]. Healthcare organizations have to resolve the problems of data integration, interoperability among various healthcare systems, and safe information. Also, the deployment of AI-oriented supply chain systems involves monetary expenses, technological resources, and human resources [72].

The introduction of AI and machine learning in the sphere of healthcare supply chain management has a great prospect of enhancing the efficiency of the working process, minimizing its costs, and providing the stable supply of the necessary medical supplies. Using predictive analytics, intelligent decision-making systems, and healthcare organizations can have a more resilient and responsive supply chain, able to support the increasing needs of the contemporary healthcare environment [73].

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AI AND HEALTHCARE DATA SYSTEMS INTEGRATION

The combination of Artificial Intelligence (AI) with health care data systems has become an essential move towards the creation of smart, efficient, and data-driven healthcare settings. The contemporary healthcare systems produce a tremendous volume of data, which come in different formats such as electronic health record, medical imaging systems, wearable health devices, laboratory information systems and hospital management systems [74]. This mass of heterogeneous data needs superior technological framework to control and analyze to enable efficient data processing, data storage and analysis. By combining AI with healthcare data system, healthcare organizations can turn raw data into actionable insights that enhance clinical decision-making, patient care and healthcare management [75].

Big data analytics are one of the technologies that enable the introduction of AI in healthcare. The healthcare data is high volume, variety, and velocity, and thus the conventional methods of data processing cannot be used to process such complex data. The technologies of big data ensure that healthcare organizations can store and process large datasets of various sources scaleably and efficiently [76]. These datasets may then be analyzed using AI algorithms to determine patterns, discover anomalies, and produce predictive information. As an illustration, AI models can process extensive groups of patient records to identify trends in diseases, the risk factors, and facilitate early diagnosis of medical conditions [77].

There has also been a significant contribution by cloud computing in facilitating AI integration with health care data systems. Cloud services offer on-demand computing capabilities that enable the medical institutions to store and process extensive amounts of medical data without requiring a large number of on-site computing resources [78]. Through cloud-based systems, hospitals and healthcare providers are able to access patient data and other analytical tools securely at various locations. Another application of cloud computing in healthcare is in collaboration of professionals and researchers and institutions by providing secure data transfer and access to health care information systems [79]. Complex datasets can be processed in real time on AI applications hosted on cloud platform thereby providing an opportunity to support faster and more accurate medical decision-making.

Edge computing is also another valuable element of AI implementation in healthcare data systems. However, whereas cloud computing offers a single point of data processing, edge computing enables data processing to be done nearer to the data creation point. Edge devices like wearable sensors, smart medical devices and mobile health apps can gather and process patient data in real time in healthcare settings [80]. With the help of direct AI algorithms incorporated in these devices, doctors can keep

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track of the patients in real-time and reveal possible health problems on the spot. An example is wearable machines with the AI-powered analytics that allow tracking a heart rate, exercise, and sleep habits and offer early warnings of possible health issues [81].

Another technological solution that promotes the incorporation of AI into a healthcare system is the Internet of Medical Things (IoMT). IoMT is an interconnected network of medical equipment, sensors, and health care applications that gather and share data relating to health-related matters. Such devices produce ongoing waves of patient data that can be processed with AI algorithms to facilitate the real-time monitoring of health to support predictive healthcare [82]. As an illustration, IoMT devices will be able to monitor chronic disease patients at home and notify health care providers in case of the appearance of abnormal health conditions.

Even though the benefits of using AI with healthcare data systems are multiple, there are a number of challenges that should be overcome to achieve successful implementation. The issue of data privacy and security is also of high concern, as the healthcare data is highly confidential information about patients. The adherence to the healthcare regulations and the confidentiality of patients are important demands when introducing AI-based systems. Also, interoperability among various healthcare information systems is imperative in facilitating smoothing of the sharing of data and integration across healthcare organizations [83].

To sum up, the combination of AI and healthcare data systems can be considered an important future development in contemporary healthcare informatics. With an integration of big data technologies, cloud computing, edge computing, and IoMT, healthcare organizations would be able to create intelligent systems, which would assist in predictive analytics, real-time monitoring, and enhanced clinical decision-making [84]. This integration eventually leads to the efficacy of healthcare services, enhanced patient outcomes, and the development of data-intensive healthcare systems.

CHALLENGES AND LIMITATIONS

Although Artificial Intelligence (AI), Machine Learning (ML), and data analytics portend health informatics with excessive benefits and progress, a number of obstacles and issues remain to prevent their mass adoption and successful implementation. These issues are caused by technological, ethical, regulatory, and organizational aspects that have to be resolved so that healthcare systems based on AI can be trustful, safe, and advantageous to both patients and medical professionals [85].

Data privacy and security is one of the most essential difficulties of AI and machine learning implementation in healthcare. Healthcare data is very sensitive information, comprising patient medical history, diagnostic report, genetic data, and treatment data. It is necessary to ensure that this data is not accessed by unauthorized personnel, attacked by cybercriminals, and does not get stolen

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[86]. As the digital health and cloud systems, as well as the interconnected medical devices, become more frequently used, the threat of cybersecurity attacks has risen. Healthcare companies should come up with stringent security measures, encryption techniques, and regulatory compliance strategies that will guarantee that patient data is confidential and secure [87].

The other significant limitation is that of data quality and availability. Machine learning algorithms are very dependent on the critical and huge amount of data in terms of quality and quantity to create valid predictions and insights. Nonetheless, there is a tendency whereby healthcare data is not complete, inconsistent, or disjointed across various healthcare systems. Even now, many hospitals and clinics continue to utilize various electronic health record systems that are not entirely compatible with one another, thus making it hard to combine information of various sources. Poor data quality may greatly decrease the accuracy and reliability of the AI models, which can result in wrong predictions or clinical suggestions [88].

Another significant challenge in healthcare informatics is interoperability problems. Interoperability is described as the capacity of various healthcare information systems, devices, and applications to communicate and share data well. Most of the healthcare facilities currently have legacy systems that do not integrate with the current AI-based technologies [89]. Consequently, the implementation of AI solutions in the current healthcare infrastructure can be complicated and expensive. It is necessary to ensure unproblematic interoperability of all systems and permit them to share data and cooperate in delivering healthcare [90].

Another relevant drawback in using AI in healthcare is ethical considerations. Application of AI algorithms in clinical decision-making is a topic that brings about the issues of transparency, fairness, and accountability. Other machine learning systems, especially deep learning systems, are considered to act as black boxes, as such their decision-making process cannot be interpreted or explained easily [91]. Clinicians in the medical field should be aware of how AI systems make their recommendations since a decision made about a patient may be directly related to their lives. The transparency and explainable AI models are thus of critical research interest in healthcare informatics [92].

On top of these, the implementation of AI technologies in healthcare systems can be slowed down by regulatory and legal issues. Healthcare is one of the most regulated fields and new technologies are forced to meet the high regulatory requirements before they are introduced into clinical practice. The regulatory bodies should take their time to review the AI-based medical devices to make sure that it is safe, reliable and effective [93]. Nevertheless, the high rate of technological advancement frequently suffers the regulatory frameworks to struggle to keep pace with the new AI development [94].

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The introduction of AI in healthcare can also be influenced by organizational and workforce issues. Healthcare workers might not be technologically skilled to use AI-based tools in ways that provide positive outcomes, and some might resist the adoption of new technology because of the threat of job loss or insecurity. The successful implementation of AI in healthcare systems implies the training of professionals and the establishment of interaction between medical professionals and data scientists. Although AI and machine learning have a great promise of revolutionizing healthcare informatics, several issues and constraints should be addressed [95]. Enhancing the quality of the data, enhancing cybersecurity, maintaining ethical AI usage, and creating supportive regulatory frameworks are some of the key steps towards successfully implementing AI-based healthcare solutions. Overcoming them will assist the healthcare systems to embrace the full potential of data-driven technologies without jeopardizing patient safety and confidence [96].

FUTURE RESEARCH DIRECTIONS

The dynamic development of Artificial Intelligence (AI), Machine Learning (ML), and data analytics has left many possibilities in terms of innovative healthcare informatics. Despite these massive advances in the usage of these technologies in predictive healthcare and supply chain management, there are still numerous areas that need research and development [97]. To make AI-based healthcare systems safe and effective, even in the real-world healthcare settings, future research directions should be oriented towards enhancing the accuracy, transparency, scalability, and ethical execution of AI-based healthcare systems [98].

The Explainable Artificial Intelligence (XAI) in healthcare is one of the most significant future research directions. Most sophisticated machine learning models, especially the deep learning algorithms are complex systems whose decision algorithms are not easily explained. The point is that in the healthcare environment, clinicians must be aware of how AI models come to conclusions and suggestions since these decisions have a direct effect on patient care [99]. The research ought to be conducted in the future with more emphasis on the creation of explainable AI models that can give a clear understanding of how decisions are made. It will assist in gaining confidence amongst medical practitioners and provide assurance that AI systems can be applied to the clinical practice safely [100]. The other area of research that can be tapped further is creation of real time predictive healthcare systems. The existing predictive analytics systems tend to be based on past data and recurring updates. Nevertheless, current healthcare settings demand systems that are able to analyze patient data in real-time and deliver insights [101]. By combining AI with real-time streams of information about wearable accessories, remote monitoring systems, Internet of Medical Things (IoMT) technologies, and others, it is possible to prevent the early identification of health issues and prompt medical

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intervention by healthcare professionals. Real-time predictive systems may be a great way to enhance the observation of the patient, especially those having chronic disease or high-risk conditions [102]. The possibility of AI-powered autonomous healthcare supply chains should also be investigated in future studies. Although the existing AI systems are capable of helping to predict the demand and maintain inventory, the more hybrid systems can be able to handle procurement, distribution, and allocation of resources without having to invest a lot of human effort into it. Independent supply chain systems would be able to study healthcare demand trends, anticipate shortages, and dynamically change inventory and distribution strategies [103]. These intelligent systems would allow healthcare organizations to react more efficiently to immediate shifts in demand, e.g., in case of the epidemic of a disease or emergency in the healthcare sector.

The other new area of study is the application of AI in healthcare systems in combination with block chain technology. The technology of block chain provides a safe and decentralized approach to the storage and distribution of sensitive healthcare data [104]. The integration of both AI and block chain would help to increase the level of data security, enhance transparency, and ensure the sharing of data between healthcare organizations safely. This combination could contribute to some significant issues connected to the data privacy, interoperability, and confidence in healthcare data management [105]. Furthermore, more studies should be done in the future to enhance the generalizability and equity of machine learning in healthcare. The current AI models are often trained on small datasets that might not be representative of various groups of people. Consequently, the models can not apply well to other demographic groups or healthcare settings [106]. The researchers should come up with stronger algorithms that are capable of adjusting to different datasets and making accurate and objective predictions among different groups of patients [107].

The other valuable research path is the one that incorporates the multidisciplinary scope of expertise of AI development in healthcare. To achieve successful AI technologies implementation, cooperation between healthcare professionals, data scientists, engineers, policymakers, and regulators is needed. Further studies in the field must focus on the integration of interdisciplinary methods to incorporate medical expertise with cutting-edge computing methodologies to come up with workable and efficient medical solutions [108].

Finally, the future studies in the field of healthcare informatics are to be devoted to the improvement of the reliability, the transparency, and the scalability of AI-based systems. The explainable AI, real-time predictive analytics, autonomous supply chains, and secure data management technologies will be significant in how the future of healthcare looks [109]. With the aim of improving the existing shortcomings and advancing novel research opportunities, AI and machine learning would play an

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important role in radically transforming the healthcare systems and bringing more effective, personalized, and predictive healthcare services [110].

CONCLUSION

The fast development of technologies in the healthcare sphere and the further growing accessibility of digital health information have reshaped the sphere of healthcare informatics greatly. Data analytics, Artificial Intelligence (AI), and Machine Learning (ML) have brought about new opportunities to enhance healthcare services, and clinical decision-making as well as healthcare operation optimization. As it was covered in this review, AI-driven analytics have been an effective tool to solve some of the most complicated problems in the contemporary healthcare systems, especially in predictive healthcare and healthcare supply chain management.

Healthcare informatics is also central to the organization, administration, and examination of large quantities of healthcare information produced by a variety of sources including electronic health records, medical image systems, wearable's, and hospital information systems. With the help of data analytics, healthcare organizations can draw valuable insights out of these datasets and this will enable healthcare professionals to make better and evidence-based decisions. With descriptive, diagnostic, predictive, and prescriptive analytics, healthcare systems would be able to know more about the past trends, the underlying causes of health issues, future health threats, and what should be done to ameliorate patient care.

Machine Learning and Artificial Intelligence technologies have empowered the functions of healthcare data analytics to a large extent. These technologies allow automated analysis of the complex data sets and identification of the pattern that could not be easily identified with the help of traditional analysis methods. Deep learning models, neural networks, support vector machines, and decision trees are just a few examples of machine learning algorithms that have proved to have good potential in medical diagnosis, disease prediction, treatment planning, and patient monitoring. Artificial intelligence is becoming accessible in order to help healthcare practitioners identify the disease in its initial stages, predict outcomes, and suggest individual treatment plans.

One of the most useful uses of AI and machine learning in the healthcare industry has become predictive analytics. Predictive models can be used to predict possible health problems before they get critical by analyzing the past data on patients and identifying risk factors. This would be a proactive strategy where healthcare professionals can take preventive measures and lower hospital readmissions and enhance overall patient outcomes. Population health management also uses predictive analytics to determine trends of specific diseases and can also be used to respond to specific groups of patients with specific healthcare intervention.

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Besides being applied in clinical settings, AI and machine learning have proven to be promising in enhancing healthcare supply chain management. The management of medical resources, pharmaceuticals, and medical equipment should be effective to have effective healthcare services. Predictive models based on AI can be used to predict the demand in medical supplies, optimize the inventory management, as well as enhance logistics and distribution processes. Such abilities prove especially significant in situations of an emergency in the sphere of public health when the access to the necessary medical facilities and their timely arrival can influence the patient care and the resilience of the healthcare system directly.

The ability of healthcare analytics has further been enhanced with the integration of AI with the current healthcare data systems such as big data systems, cloud computing, edge computing, and Internet of Medical Things (IoMT) systems. The technologies allow real-time data processing, remote monitoring of patients, and more intelligent and responsive predictive modeling, a process that facilitates the creation of smarter and more adaptable healthcare systems. Nevertheless, the process of using AI-driven medical technologies has a number of challenges and limitations despite all the above advantages.

The most prominent ones are data privacy and data security concerns, data quality issues, absence of interoperability between healthcare systems, and ethical concerns related to AI-based decision-making. Also, the inability to implement AI in healthcare settings is hindered by the complexity of machine learning models and the necessity to comply with the regulatory standards. To solve these issues, researchers, healthcare providers, developers of technologies, and policymakers should work together to achieve the responsible and ethical use of AI technologies.

In the future, further studies in the field of healthcare informatics must be aimed at the creation of more transparent, explainable, and effective AI systems that can work in various healthcare settings effectively. Explainable AI, real-time predictive analytics, autonomous healthcare supply chains, and secure data-sharing technologies are some of the innovations that will become important in defining the future of healthcare systems.

To sum up, the implementation of data analytics, artificial intelligence, and machine learning in healthcare informatics can bring a major change in healthcare delivery and management. Healthcare organizations can create more predictive, personalized, and efficient healthcare systems by using the power of analytical technology. Further studies, technological progress, and joint work will be needed to achieve the full potential of AI-informed healthcare solutions and guarantee better health outcomes of patients across the globe.

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