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Artificial Intelligence in Healthcare: A Multidisciplinary Review of Applications and Challenges

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Abstract

The application of artificial intelligence (AI) in contemporary healthcare systems is leading to the fusion of medicine, computer science, biomedical engineering, health informatics, and public health to create intelligent and data-enabled healthcare systems. This review provides a multidisciplinary overview of the basics, applications, implementation challenges, and future trends of AI in healthcare. The review highlights how AI enables clinical decision-making, preventive healthcare, patient-centric healthcare, healthcare processes, precision medicine, and population healthcare through technologies such as machine learning, explainable AI, federated learning, digital twins, the Internet of Medical Things (IoMT), and generative AI. The review also covers major implementation challenges such as data quality, interoperability, clinical validation, privacy, cybersecurity, algorithmic bias, and regulation. The results show that although AI has enhanced the quality, efficiency, and access to healthcare services, its success relies on interdisciplinarity, governance, strong digital infrastructure, and continual assessment of clinical outcomes. Research gaps are outlined, along with the requirement to develop a trustworthy, explainable, and human-centric AI system that can support sustainable and equitable healthcare services. Overall, AI can revolutionize healthcare worldwide by providing efficient and personalized medical services.

Keywords: Artificial Intelligence (AI); Healthcare; Multidisciplinary Healthcare; Clinical Decision Support; Precision Medicine; Explainable Artificial Intelligence; Federated Learning; Digital Health; Responsible AI; Population Health.

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1. INTRODUCTION

AI technology has proven to be one of the most important breakthroughs in modern medicine. Machine learning, deep learning, natural language processing, computer vision, and data analytics have allowed healthcare providers to analyze huge amounts of clinical and biomedical information fast and accurately[1]. Digital transformation of healthcare through the use of electronic health records, medical imaging, wearables, genomics, and IoMT technologies has resulted in the accumulation of large quantities of health data, which can be further analyzed for practical insights through AI technologies 2. Thus, AI technologies are used more and more in healthcare institutions for diagnostics, treatment planning, operations optimization, and evidence-based decision-making.

In addition to technological innovation, effective incorporation of AI in healthcare necessitates cooperation between various fields of study such as medicine, computer science, biomedical engineering, health informatics, public health, ethics, and law[3]. All these disciplines together form the basis for the design, validation, deployment, and governance of intelligent healthcare systems that are scientifically credible, ethical, and socially acceptable. With the continuous evolution of healthcare toward personalized and preventive care, knowledge of multidisciplinary aspects, as well as implementation issues related to the use of AI, has become necessary for scientists, doctors, healthcare policymakers, and administrators[4]. The present paper thus reviews the paradigm shift brought about by AI in the field of healthcare from a multidisciplinary perspective.

1.1 Background and Context

There is an increasing demand on healthcare systems all over the world caused by the increasing burden of diseases, an ageing population, shortages of personnel, increased costs in healthcare, and the desire for quality health services[5]. The problems mentioned have led to the use of AI as a tool that helps to make improvements in healthcare delivery. AI technologies can be used to analyze complex healthcare data, assist in clinical decision-making, automate administrative processes, support personalized medicine, and enhance disease surveillance. Integration of intelligent technologies in healthcare delivery is leading to the transformation of traditional healthcare systems into interconnected and data-based ecosystems[6].

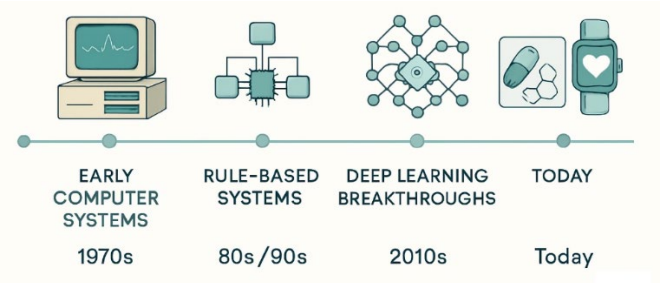

Figure 1. Evolution of AI in Healthcare

1.2 Objectives of the Review

The major aims of this review include:

- To investigate the interdisciplinary backgrounds underlying the creation and implementation of AI within healthcare.
- To consider the transformational impact of AI in the context of the entire continuum of healthcare from clinical practice, healthcare management, precision medicine, and population health.
- To explore the technical, clinical, ethical, legal, and regulatory implications of responsible AI implementation.
- To survey current trends in novel AI technologies and their significance for the future of healthcare.
- To discover existing research gaps and define directions for future research on sustainable and trustworthy AI-based healthcare.

1.3 Importance of the Topic

The emergence of AI is changing the nature of healthcare through enhanced diagnosis, personalized treatment, intelligent healthcare systems, and decision-making related to public healthcare. In addition to enhancing performance in healthcare through the use of AI technologies, the implications of using AI technologies in healthcare practice have also grown beyond mere performance issues and include ethical, regulatory, workforce, and access considerations to healthcare services[7]. A multidisciplinary understanding of AI becomes imperative to ensure the safe and proper application of technological developments in healthcare. This study offers important information about the application of AI technologies in transforming the healthcare system through review.

2. MULTIDISCIPLINARY FOUNDATIONS OF AI-DRIVEN HEALTHCARE

Through AI, the health sector has evolved from a technology-based innovation to a complex system that encompasses the application of clinical expertise, computational intelligence, biomedical engineering, health informatics, and public health[8]. The increasing availability of electronic health records, medical imagery, genomics, wearables and health IT platforms has provided opportunities for intelligent healthcare systems which enable evidence-based decision-making and personalized patient care. However, the successful adoption of AI goes beyond algorithm creation and entails cooperation among different fields to ensure clinical feasibility, adherence to ethical standards, technical soundness, and sustainable healthcare provision[9]. This section outlines the multidisciplinary foundations behind AI healthcare through data-based clinical intelligence and interdisciplinary cooperation, among others.

2.1 Data-Driven Healthcare and Intelligent Clinical Decision Support

The healthcare industry has shifted from the previous experiential approach to a new data-centric strategy where clinical decisions are now informed by health data. With the increasing adoption of Electronic Health Records (EHRs), laboratory data, imaging modalities, genomics sequencing techniques, and wearables, there has been an explosion of healthcare data in both structured and unstructured forms[10]. These various types of data inform the patient's health condition, disease progression, health outcomes, and utilization of healthcare services, thus creating a base for the intelligent healthcare system.

AI uses machine learning, deep learning, natural language processing, and predictive analytics to translate heterogeneous datasets into clinically useful knowledge. Prior to building models, there is a series of procedures involved in preprocessing healthcare data such as cleaning, normalization, feature extraction, and multimodal fusion to enhance the quality of the data and make the analysis process efficient[11]. The combination of clinical data with imaging, genomics, laboratory, and physiological data makes it possible for AI to build patient profiles.

The result of such an approach includes the creation of smart Clinical Decision Support Systems (CDSS), which help medical practitioners during the diagnosis and therapy stages. CDSS are capable of identifying disease patterns, forecasting patients' risks, providing evidence-based recommendations, and issuing relevant clinical alerts[12]. Such systems do not substitute for doctors, but rather operate as decision-support technology, increasing the efficiency of clinical operations and improving safety standards.

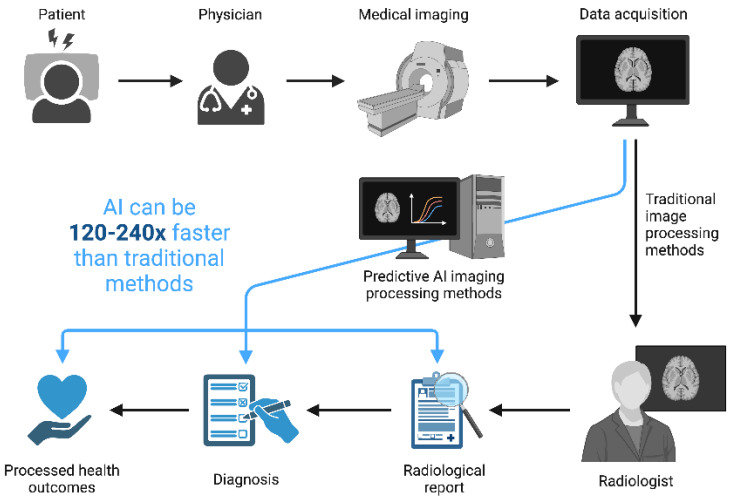

Figure 2. AI-Enabled Medical Imaging and Clinical Decision Support Workflow

2.2 Multidisciplinary Integration in AI-Based Healthcare

Implementation of AI in healthcare cannot be done effectively via technology innovation only as it involves clinical, technical, ethical, organizational, and regulatory aspects of healthcare issues[13]. Medical specialists offer the needed clinical expertise in the identification of the healthcare problem, validation of the AI model, and ensuring that the recommendations provided by the AI model meet the standards of evidence-based medicine. Their participation is necessary for ensuring the safety of patients, diagnostics accuracy, and clinically useful application of AI innovations[14].

Computer science, biomedical engineering, health informatics, and data science form the technological base for the realization of healthcare based on AI. Machine learning algorithms, intelligent systems, smart medical devices, sensors, and healthcare information systems help to efficiently collect, analyze, and manage healthcare information[15].

In addition to knowledge and proficiency in technology and clinical practice, there are other fields such as public health, ethics, law, and healthcare administration which contribute equally well towards ensuring proper utilization of AI[16]. It is because these fields concern problems such as confidentiality of patient information, protection of their data, justice in algorithms, transparency, accountability, and regulation in healthcare provision.

Table 1. Multidisciplinary Contributions to AI-Driven Healthcare

Discipline	**Primary Contribution**	**Representative AI Technologies/Tools**	**Healthcare Outcomes**
Medicine & Clinical Sciences	Clinical diagnosis, treatment planning, patient management, validation of AI models	Clinical Decision Support Systems (CDSS), predictive diagnostics	Improved diagnostic accuracy and patient outcomes
Computer Science & AI	Development of machine learning algorithms, deep learning models, and intelligent software	Machine Learning, Deep Learning, Natural Language Processing, Computer Vision	Intelligent clinical decision-making and automation
Biomedical Engineering	Design of smart medical devices, biosensors, imaging systems, and wearable technologies	IoMT devices, robotic surgery systems, medical imaging equipment	Continuous patient monitoring and precision healthcare

Health Informatics & Data Science	Integration, preprocessing, storage, and analysis of healthcare data	Electronic Health Records (EHR), data analytics platforms, predictive models	Efficient healthcare data management and evidence-based care
Public Health	Population health surveillance, disease prediction, health policy support	Predictive epidemiological models, health surveillance systems	Improved disease prevention and healthcare planning
Ethics, Law & Healthcare Governance	Regulation, privacy protection, fairness, transparency, and accountability	AI governance frameworks, Explainable AI (XAI), regulatory standards	Responsible, trustworthy, and legally compliant AI implementation

2.3 Emerging Intelligent Healthcare Ecosystem

The fast-paced growth in technology is leading to the evolution of healthcare into an interconnected intelligent ecosystem that leverages new AI technology. Explainable AI (XAI), Federated Learning, IoMT, and Digital Twin are among those technologies that have greatly increased the functionality of intelligent healthcare system[17]. Such innovations make it possible to enhance clinical decisions, monitor patients continuously, provide better data privacy, and offer more personalized healthcare services without experiencing the limitations of traditional AI systems.

Another example of digital technology used in healthcare is Generative AI and Large Language Models (LLMs)[18]. The use of such technologies helps healthcare specialists to perform clinical documentation, search for medical information, communicate with patients, receive medical education, and conduct scientific research because they analyze and generate healthcare information at a very fast pace.

Integration of AI technology with the existing connected healthcare system is resulting in the creation of smart hospitals and a digital health system ecosystem. Intelligent medical devices, cloud computing, real time analytics, integrated information systems, and automation using AI all play a role in making healthcare delivery more predictive and data driven[19]. With continued evolution of these technologies, multi-disciplinary cooperation will be critical to ensure that intelligent healthcare systems become clinically and ethically viable[20].

3. TRANSFORMATION OF HEALTHCARE THROUGH AI

The use of AI is revolutionizing the healthcare industry through a total transformation of the way in which health services are provided, administered, and measured. AI is no longer just an enabling tool that helps diagnose illnesses, but an essential part of any modern healthcare system in that it helps deliver preventive medicine, optimize clinical processes, enhance patient

services, and manage populations' health[21]. Combining intelligent algorithms with digital technologies in health care allows for making informed decisions based on evidence, improving effectiveness, and enhancing patient outcomes. Therefore, it facilitates a move away from a reactive model of health care to a proactive and personalized one. This section discusses the transformational power of AI in healthcare delivery and healthcare operations.

3.1 AI Across the Healthcare Continuum

AI technology is increasingly being used to facilitate healthcare for patients during all stages of their healthcare experience, from the prevention of diseases to rehabilitation and long-term health maintenance. In terms of preventive medicine, AI technology makes use of various data on demographics, behavior, environment, and clinical factors to find people at increased risk of developing chronic conditions and implement measures to address the risk of developing these conditions before any clinical manifestation occurs[22].

In the field of primary care and specialized medicine, AI supports health practitioners through its ability to enhance diagnostic efficacy, optimize treatment plans, and inform evidence-based decision making. Smart clinical tools use patient files, laboratory results, radiology images, and physiological measures to help doctors make correct diagnoses and prescribe proper treatments. This enables effective healthcare provision without variations in diagnosis.

Also, AI is used in rehabilitation and long-term care by providing constant monitoring and personalizing rehabilitation[23]. The use of wearable technologies, intelligent rehabilitation aids, and monitoring systems helps doctors monitor patients' development and treatment efficiency, as well as modify rehabilitation programs based on the needs of a patient. This kind of technology is especially useful in treating chronic diseases, neurological problems, cardiovascular rehabilitation, and the elderly.

3.2 AI for Healthcare Operations and Patient-Centered Care

In addition to applications within clinical medicine, AI is revolutionizing the functioning of healthcare organizations, making them more efficient and sustainable[24]. Analytical tools based on AI enable the optimal functioning of hospitals through intelligent scheduling, patient triaging, resource allocation, inventory management, and predictive maintenance of healthcare equipment. Such changes decrease the workload of healthcare institutions, reduce waiting times, improve resource utilization, and boost the performance of healthcare institutions[25].

AI has contributed to a greater extent towards making healthcare more patient-centric by using technologies that make the communication between patients and healthcare providers easier. Telemedicine systems based on AI allow for virtual visits, remote diagnosis, scheduling appointments, and follow-ups irrespective of patients' locations[26]. Moreover, virtual health assistants and conversational chatbots powered by AI help patients stay informed about their health condition, take medications, and manage chronic diseases.

A significant change relates to the accessibility and equality in healthcare. Telemedicine applications, mobile health apps, and remote monitoring tools provide access to healthcare services to people living in rural areas, to the disadvantaged and those with limited mobility[27]. Through decreasing the physical distance between patients and doctors and making healthcare accessible, AI promotes more equal healthcare systems.

Table 2. Transformation of Healthcare Delivery Through AI

Healthcare Domain	Role of AI	Key Technologies	Major Outcomes
Preventive Healthcare	Predicts disease risk and supports early intervention	Machine Learning, Predictive Analytics	Early detection and disease prevention
Primary & Specialized Care	Assists diagnosis and treatment decisions	CDSS, Deep Learning, Medical Imaging AI	Improved accuracy and patient safety
Rehabilitation & Long-Term Care	Monitors recovery and supports personalized care	AI Wearables, IoT Devices, Remote Monitoring	Better recovery and chronic care
Healthcare Operations	Optimizes workflows and resource management	Workflow Automation, AI Scheduling	Greater efficiency and reduced waiting time
Patient-Centered Care	Supports telemedicine and patient engagement	Telemedicine, Conversational AI, Mobile Health	Better access and patient satisfaction
Precision & Population Health	Enables personalized medicine and disease surveillance	Genomic AI, Predictive Modeling	Personalized care and improved public health

3.3 AI for Precision and Population Health

AI is increasingly contributing to personalized medicine by making it possible for the use of individualized health care approaches taking into account biological and clinical specifics of patients. Using machine learning, algorithms analyze genomic data along with information on a patient's medical history, images, lab results, and lifestyle aspects in order to distinguish sub-types of diseases, predict treatment outcomes and provide personalized therapy solutions[28].

The application of AI to genomic medicine contributes greatly to personalized health care through making it possible to analyze big genomic and multi-omics data sets. Using advanced computational methods, the technology enables the discovery of disease-specific genomic

variants, biomarkers, and precision diagnostics of complex diseases like cancer, cardiovascular diseases, and rare genetic disorders[29].

On the population level, AI facilitates predictive analytics, disease surveillance, and public health intelligence through constant analysis of healthcare data, epidemiological data, environmental data, and digital surveillance systems. Models that utilize AI help to detect outbreaks early, make predictions about the demand on healthcare resources, and monitor emerging public health threats[30]. The current COVID-19 pandemic has shown the significance of AI in predicting an outbreak, conducting contact tracing, making resource plans, and making decisions in healthcare.

4. CHALLENGES AND RESPONSIBLE IMPLEMENTATION OF AI IN HEALTHCARE

Though the advancements of AI in the sphere of healthcare have been striking, the implementation of AI in healthcare has to overcome many barriers related to technical issues, clinical practice, ethics, laws, and organization of work. The potential of AI in the healthcare sector to contribute to its development, improvement of the quality of services and operations, and decision-making is evident; however, the process of implementation of AI into practice is more complicated than the creation of algorithms[31]. The implementation of AI in healthcare practice implies the presence of good quality healthcare data, sufficient technological infrastructure, governance, regulation, and cooperation of clinicians, engineers, policy-makers, and healthcare institutions. The following sections cover major barriers to implementation and the necessary principles of implementation of AI in healthcare.

4.1 Technical and Clinical Implementation Challenges

One of the major factors hindering successful implementation of AI solutions is the quality of the healthcare data. It is gathered from several sources including EHRs, laboratory systems, medical imaging, and wearable devices. The heterogeneity of the dataset combined with missing data, inconsistencies, and lack of data standardization results in lower performance of the models. Thus, ensuring high-quality data, interoperability and its standardized exchange is one of the main preconditions for developing efficient AI solution[32].

Clinical validation is another major issue, which has to be overcome because AI models performing well during the development stage can show very different results in the real clinical setting. This situation is caused by differences in the demographics of patients, prevalence of diseases, healthcare infrastructure, and clinical workflow. Therefore, external validation, monitoring, and updating of the model are needed for successful operation of the AI system.

The incorporation of AI into daily clinical practice procedures also poses some practical problems. Health practitioners need AI that is accurate, user-friendly, and able to work well with the existing hospital information systems, as well as offering timely decision-making

support. Furthermore, keeping up the robustness of the models in dynamic clinical settings and reducing complexity are critical for successfully adopting AI technology[33].

4.2 Ethical, Legal and Regulatory Considerations

Use of AI technology in healthcare poses challenges of data security and patient privacy as well as the issue of cybersecurity. The AI systems work on sensitive personal and medical information, thus making healthcare organizations susceptible to cyber-attacks. Therefore, robust data protection, secure data exchange, and the use of cryptographic technology and adherence to national and international data privacy legislation are crucial in ensuring that the patients' data is kept confidential.

Another ethical challenge in using AI in healthcare includes issues of biases and transparency in AI models. Presence of biases in the healthcare data might result in uneven performance of diagnostics by the algorithm across various demographics, and therefore might contribute to health disparity. In addition, complex deep-learning algorithms are opaque black boxes that make it hard for the clinicians to determine how the decisions are made. Explainable AI is therefore a significant way of ensuring transparency and interpretability.

From the perspective of law and regulation, proper governance frameworks are essential to ensure accountability for AI-enabled clinical decision-making. Issues related to liability, regulatory approval, safety requirements, and ongoing monitoring after deployment continue to be a matter of active debate globally[34]. It is essential for governments, regulatory bodies, healthcare providers, and technology developers to work together to develop standard guidelines that encourage responsible AI development and patient safety.

4.3 Sustainable Future of AI-Enabled Healthcare

Sustainability of AI applications in the field of medicine is highly contingent upon the adoption of the human-oriented philosophy in which intelligent systems will be seen as an assistance to medical staff, not as a replacement of healthcare professionals. AI needs to serve as a technological aid that would help in improving the clinical knowledge base, making correct decisions and minimizing bureaucratic work without sacrificing human decision-making, human empathy, and patient-centeredness.

Workforce readiness becomes another key aspect of sustainable development of AI in the medical field. Medical workers need ongoing education and training in order to comprehend the nature of AI and its potential, interpret algorithms' recommendations, and apply the intelligent technologies in the field of their work[35]. At the same time, engineers and developers of AI must have a good understanding of healthcare processes and needs.

AI-assisted healthcare of the future will require responsible governance, international cooperation, and robust digital health infrastructure. The establishment of interoperable healthcare systems, cloud computing systems, safe data exchange systems, and smart medical devices will improve the healthcare system while fostering innovation. However, international

cooperation between the mentioned parties will help to develop ethical principles, regulations, and digital health ecosystems that would be able to provide high-quality and patient-centered healthcare.

Table 3. Comparative Analysis of Recent Studies on AI in Healthcare

Author(s) & Year	Study Focus	Major Findings	Research Gap / Limitation
Udegbe et al. (2024)[36]	Systematic review of AI applications and challenges in healthcare	Reported significant improvements in diagnosis, treatment support, and healthcare management through AI technologies.	Limited discussion on implementation frameworks and long-term clinical validation.
Wang & Li (2024)[37]	AI in public health education	Demonstrated that AI enhances public health education through personalized learning, intelligent tutoring, and digital health awareness.	Primarily focused on educational applications with limited emphasis on clinical implementation.
Younis et al. (2024)[38]	Systematic review and meta-analysis of AI tools in healthcare	Highlighted broad applications of AI while identifying challenges related to ethics, data quality, explainability, and regulatory compliance.	Greater need for standardized evaluation frameworks and multicenter clinical validation.
Yu, Beam & Kohane (2018)[39]	AI in modern healthcare	Established AI as a transformative technology capable of improving diagnosis, prediction, and personalized medicine across healthcare systems.	Discussed future opportunities but provided limited evidence on large-scale real-world deployment.
Zhang & Zhang (2023)[40]	Ethics and governance of trustworthy medical AI	Emphasized transparency, accountability, fairness, and governance as essential requirements for trustworthy medical AI.	Focused mainly on governance principles with limited discussion of technical implementation challenges.

5. DISCUSSION

AI has become a disruptive technology that is revolutionizing the delivery of healthcare through interprofessional collaboration, intelligent use of data, and constant innovation in technologies. The previous sections of this review article have already shown how AI contributes to healthcare throughout the care continuum, how it improves the operations of healthcare, promotes precision and population medicine, and at the same time creates a number of technical, ethical, legal, and organizational issues. While significant efforts have already been made in incorporating AI technologies into modern healthcare organizations, their successful long-term implementation requires a careful balance between innovation and clinical validation, governance, and patient-centeredness. This discussion attempts to interpret the main conclusions from the review, discuss their implications, outline the existing research gaps and limitations, and formulate the future directions for research.

5.1 Interpretation and Analysis of Findings

The results of this study suggest that AI has progressed from being just another computing technology to being a multidisciplinary factor behind changes in the healthcare system. According to the literature, AI is shaping the delivery of healthcare services in all possible aspects, ranging from preventive medicine and decision support tools through hospital management and precision medicine to public health monitoring. The progress in machine learning, deep learning, explainable AI, federated learning, and digital health has brought about significant improvements in terms of efficiency, diagnostics, and treatment personalization in the field. Nonetheless, the review has also revealed that technical progress by itself is not enough for proper implementation. It is only through multidisciplinary efforts that intelligent technologies can be clinically reliable and ethically sound.

5.2 Implications and Significance

Increased usage of AI has several implications for healthcare organizations, researchers, technology developers, and policy-makers. For healthcare organizations, the implications of AI include increased efficiencies in processes, increased optimization of resources, better clinical decision making, and provision of patient-centered care. For researchers and developers, the implications from this review include the necessity of designing AI systems that are explainable, transparent, and interoperable. Finally, for policy-makers, the implications include the necessity of creating governance frameworks, regulations, and developing the workforce in order to foster innovation and safeguard patient safety and privacy. All of these implications prove that AI will become increasingly critical for efficient and resilient healthcare systems.

5.3 Research Gaps and Limitations

Despite considerable advances made in AI-supported healthcare, there still persist certain research areas that impede the wide implementation of this technology. The majority of existing studies concentrate mainly on the design of algorithms and their accuracy. Simultaneously, relatively less attention is paid to the validation of these algorithms, their interoperability within

healthcare institutions, practical implementation, and interdisciplinary evaluation. There are still issues such as explainability, algorithm fairness, cybersecurity, regulatory compatibility, and workforce preparedness that do not receive sufficient coverage in present-day literature. The current review is additionally restricted by the fact that it is based solely on peer-reviewed articles and, consequently, does not provide an analysis of innovative industrial development.

5.4 Future Research Directions

Moving forward, future research efforts ought to center around creating reliable, transparent, and human-oriented AI applications, which can be incorporated in day-to-day clinical practice without posing any safety hazards. More attention needs to be paid to multicenter validation of clinical use, interoperable health care infrastructure, privacy-preserving machine learning methods, digital twins, multimodal AI, and language models to make healthcare decisions more efficient while ensuring patients' privacy. The methods of minimizing algorithmic biases, increasing model transparency, and creating standardized evaluation frameworks that enable comparisons between various healthcare environments should also be studied. Collaboration between healthcare organizations, educational establishments, industry, and regulating agencies on an international level will contribute to the fast-paced development of AI technologies for healthcare.

6. CONCLUSION

AI has emerged as a revolutionary technology in contemporary healthcare by facilitating data-driven decision-making in clinical practice, improving healthcare provision, increasing efficiency, and facilitating personalized and population medicine. The current review has shown that the effective application of AI involves not only innovative technological solutions but also interdisciplinary cooperation between medicine, computer science, biomedical engineering, health informatics, public health, ethics, and regulatory sciences. Although AI provides many possibilities for the improvement of the quality, accessibility, and sustainability of healthcare, there are a number of key challenges that need to be addressed in order to realize its potential. These challenges include data quality issues, clinical validation, interoperability, transparency, privacy, cybersecurity, and others. Future achievements in this field will be determined by the creation of trustworthy, explainable, and human-centric AI powered by digital infrastructure and regulation along with interdisciplinary cooperation. By merging technological progress with clinical responsibility and ethical governance, AI is able to revolutionize the sphere of healthcare turning it into a more intelligent, equitable, and patient-centered system.

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