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Artificial Intelligence in Medicine. Are we Ready for this Challenge? – A Literature Review

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Abstract

Artificial Intelligence (AI) has emerged as a powerful tool in the field of medicine, offering opportunities to enhance healthcare delivery, improve patient outcomes, and optimize resource allocation. This review provides a comprehensive examination of the applications of AI in medicine, focusing on key areas such as diagnostic support, personalized treatment, drug discovery and development, healthcare management, and public health.

The review explores the benefits and limitations of AI in each area, discussing examples of AI-assisted diagnosis, image analysis, and predictive models for treatment outcomes. It also examines the role of AI in tailoring treatment plans to individual patients, utilizing algorithms to predict drug efficacy and adverse effects, and optimizing hospital operations and resource allocation. Additionally, the review explores the utilization of AI for predicting disease outbreaks, managing public health, and addressing healthcare disparities.

Challenges and considerations related to AI integration in medicine are discussed, including data quality and privacy concerns, algorithm bias, and the need for interpretability. Strategies are proposed to address these challenges, emphasizing the importance of data governance, ethical guidelines, and explainable AI. Furthermore, the review identifies key areas of research and collaboration needed for the responsible integration of AI, such as algorithmic

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fairness, human-AI collaboration, and longitudinal validation studies.

By highlighting the readiness challenges and providing recommendations, this review calls upon stakeholders in the healthcare industry to work together to ensure the responsible integration of AI in medicine. Collaboration among healthcare institutions, researchers, policymakers, and AI developers is essential to address the challenges, develop ethical guidelines, and drive advancements in AI technology. Ultimately, the integration of AI in medicine has the potential to revolutionize healthcare delivery, enhance clinical decision-making, and improve patient outcomes, paving the way for a more efficient and effective healthcare system.

Keywords: AI, Artificial intelligence, medicine, healthcare, challenges, readiness, recommendations

INTRODUCTION

Artificial Intelligence (AI) has emerged as a transformative technology with immense potential to revolutionize healthcare. In the field of medicine, AI refers to the utilization of advanced algorithms and computational models to analyze complex medical data, make clinical predictions, and support decision-making processes. The integration of AI in healthcare holds promise for improving diagnostic accuracy, personalized treatment strategies, drug discovery, and healthcare management. However, as AI continues to gain momentum in the medical domain, it is crucial to assess our readiness to face the challenges associated with its implementation (1, 2, 3).

The role of AI in healthcare has witnessed significant growth in recent years. Advanced machine learning algorithms, deep learning models, and natural language processing techniques have enabled the development of AI systems capable of analyzing vast amounts of medical data, including electronic health records, medical images, and genomic information. These AI-powered systems can assist healthcare professionals in diagnosing diseases, identifying treatment options, and predicting patient outcomes. Furthermore, AI algorithms can aid in optimizing healthcare workflows, enhancing resource allocation, and managing population health (4, 5).

Despite the promising applications of AI in medicine, there are notable challenges that need to be addressed to ensure its successful integration. The readiness challenge encompasses multiple dimensions, including data quality and privacy, algorithm bias and interpretability, and the regulatory and legal framework surrounding AI in healthcare. The quality and availability of healthcare data, along with concerns about privacy and security, pose significant obstacles to the widespread implementation of AI. Additionally, issues related to algorithmic bias and interpretability raise questions about fairness, transparency, and the ethical implications of AI-driven decisions. Furthermore, the current regulatory frameworks may not be adequately prepared to address the complexities of AI in medicine, necessitating the development of robust guidelines and policies (4, 6, 7).

This review article aims to examine the readiness challenge associated with the adoption of AI in medicine. By exploring the definition of AI in medicine and providing an overview of its increasing role in healthcare, we will delve into the challenges that hinder its full realization. Through an analysis of data quality, privacy concerns, algorithmic bias, interpretability issues, and the regulatory landscape, we will assess the readiness of healthcare systems to leverage AI effectively. Ultimately, this article will contribute to the understanding of the current state of AI in medicine and provide recommendations for future directions to ensure responsible and beneficial implementation.

METHODS

The methodology employed for conducting this literature review on the topic "AI in Medicine: Are We Ready for the Challenges We Face" typically involves systematic and comprehensive steps to gather and analyze relevant literature. We followed a research question formulation, clearly defining the research question (objective) of the literature review, “exploring the readiness of AI in medicine and the challenges faced”. We conducted a thorough search of relevant databases PubMed, IEEE Xplore, Scopus, Web of Science, and ACM Digital library. The search terms we included were combinations of the keywords "AI," "artificial intelligence," "medicine," "healthcare," "challenges," "readiness," and related terms. We established as inclusion criteria all the publications included in the period of time from 2010 until 2022 and reviewed the identified articles based on their titles, abstracts, and full texts to determine their relevance and eligibility for inclusion in our review. We analyzed the data and identified common themes, trends, and challenges related to the readiness of AI in medicine. And also we have compared and contrasted the findings across the selected studies, highlighting the similarities and differences, identifying any gaps or inconsistencies in the literature and providing in this way a comprehensive synthesis of the current knowledge.

RESULTS

Artificial intelligence has revolutionized not only the field of medicine but also healthcare and has shown a marvelous potential increasing the accuracy and efficiency of the diagnostic tools, drug discovery, personalized treatment and not only (table 1):

Table 1. An overview of the various applications of AI in medicine, including diagnostic support, personalized treatment, drug discovery, and healthcare management

AI Applications in Medicine	Description
Diagnostic Support	AI-assisted diagnosis and image analysis have transformed the field of medicine. This includes applications in radiology, pathology, and dermatology, aiding in accurate diagnoses and treatment decisions.
Personalized Treatment and Precision Medicine	AI plays a crucial role in tailoring treatment plans to individual patients, utilizing predictive analytics and treatment recommendation systems to optimize patient outcomes.
Drug Discovery and Development	AI-driven approaches are revolutionizing the drug discovery process, enabling virtual screening, drug repurposing, and predicting drug efficacy and adverse effects.
Healthcare Management and Resource Optimization	AI applications in healthcare management focus on optimizing hospital operations, resource allocation, predicting disease outbreaks, and managing public health to enhance efficiency and patient outcomes.

DISCUSSION

AI Applications in Medicine - Diagnostic Support

Artificial Intelligence (AI) has revolutionized the field of medicine, particularly in diagnostic support. AI-assisted diagnosis and image analysis have shown tremendous potential in enhancing the accuracy and efficiency of medical diagnoses. We find examples of AI-Assisted Diagnosis and Image Analysis in:

1. *Radiology*: AI algorithms have been developed to analyze medical imaging data such as X-rays, CT scans, and MRIs. For instance, deep learning models can detect abnormalities in lung images, aiding in the early diagnosis of lung cancer. Studies by Esteva et al. (2017) and Ardila et al. (2019) have demonstrated the effectiveness of AI in diagnosing various diseases using radiological images (1,8).
2. *Pathology*: AI systems have been employed to assist pathologists in analyzing histopathological images. These models can accurately detect cancerous cells, classify different types of tumors, and provide prognostic insights. Notably, a study by Coudray et al. (2018) showcased the potential of AI in diagnosing lung cancer through histopathological image analysis (9).
3. *Dermatology*: AI algorithms have been trained to analyze skin images and aid in the diagnosis of dermatological conditions. By comparing images to vast databases, these systems can provide differential diagnoses and suggest appropriate treatments. The work by Esteva et al. (2017) demonstrated the success of AI in diagnosing skin cancer, achieving comparable accuracy to dermatologists (8).

Benefits and Limitations of AI in Diagnostic Support are described in the table 2 below:

Table 2. The benefits and limitations of AI in diagnostic support

Benefits of AI in Diagnostic Support	Descriptions
Increased Accuracy	AI algorithms can process vast amounts of medical data and identify patterns that may be imperceptible to human observers, leading to enhanced diagnostic accuracy.
Efficiency and Time-Saving	AI systems can analyze medical images and provide preliminary diagnoses rapidly, enabling faster treatment decisions and reducing waiting times.
Accessibility	AI technology can be deployed in resource-limited settings, allowing access to expert diagnostic support in areas with a shortage of healthcare professionals.
Augmentation of Expertise	AI assists healthcare professionals by providing additional insights and reducing diagnostic errors through its ability to analyze complex datasets.

Limitations of AI in Diagnostic Support	Descriptions
Lack of Generalizability	AI models trained on specific datasets may have limited generalizability when applied to different populations or healthcare systems, potentially leading to inaccurate diagnoses.
Interpretability	Deep learning models often operate as "black boxes," making it challenging to understand how the algorithm arrives at its diagnoses. The lack of interpretability can raise concerns regarding trust and accountability.
Data Bias	AI algorithms trained on biased datasets may perpetuate or amplify existing biases in healthcare, leading to disparities in diagnoses and treatment recommendations.
Regulatory Challenges	The integration of AI in clinical practice requires navigating regulatory frameworks, including ensuring compliance with privacy and ethical guidelines.

AI Applications in Medicine - Personalized Treatment and Precision Medicine

Personalized treatment and precision medicine have gained significant attention in healthcare, aiming to tailor medical interventions to individual patients based on their unique characteristics. Artificial Intelligence (AI) plays a crucial role in this paradigm shift, enabling the analysis of vast amounts of patient data and the development of predictive model, exploring the role of AI in personalized treatment, including the use of AI algorithms for predicting treatment outcomes is important.

Role of AI in Tailoring Treatment Plans to Individual Patients:

1. Predictive Analytics: AI algorithms leverage patient data, including electronic health records, genomic information, and medical imaging, to develop predictive models. These models can assess patient risk, prognosis, and response to treatment. By considering individual patient factors, such as demographics, genetic markers, and co-morbidities, AI enables the tailoring of treatment plans to optimize patient outcomes (10,11).

2. Treatment Recommendation Systems: AI-driven treatment recommendation systems use machine learning techniques to analyze patient data and suggest personalized treatment options. These systems consider various factors, including patient demographics, medical history, genetic profiles, and treatment guidelines, to provide clinicians with evidence-based recommendations for optimal treatment selection (2).

Use of AI Algorithms for Predicting Treatment Outcomes:

1. Treatment Response Prediction: AI models can predict individual patient responses to specific treatments. By integrating patient data with knowledge from clinical trials and real-world evidence, AI algorithms identify patterns and factors that influence treatment response. This enables

healthcare providers to make informed decisions regarding treatment selection and dosage adjustments (3).

2. *Adverse Event Prediction*: AI algorithms can analyze patient data to predict the likelihood of adverse events associated with specific treatments. By considering patient characteristics, biomarkers, and treatment-related factors, AI models assist in identifying patients at higher risk of adverse events, allowing proactive interventions and personalized risk mitigation strategies (2).

AI Applications in Medicine - Drug Discovery and Development

The process of drug discovery and development is a complex and time-consuming endeavor. However, Artificial Intelligence (AI) has emerged as a powerful tool in this field, offering new opportunities to accelerate and enhance the process.

AI-driven Approaches for Drug Discovery and Repurposing:

1. *Virtual Screening*: AI algorithms can efficiently screen large libraries of compounds to identify potential drug candidates. Machine learning models can analyze molecular structures and properties to predict the likelihood of a compound's efficacy against a specific target. For example, a study by Gómez-Bombarelli et al. (2018) showcased the successful use of AI in the discovery of new high-performance materials for drug delivery (12).

2. *Drug Repurposing*: AI algorithms can analyze vast amounts of data, including electronic health records, genomic information, and scientific literature, to identify potential alternative uses for existing drugs. By identifying new targets or indications for approved drugs, AI facilitates the repurposing of drugs, reducing the time and cost associated with traditional drug development. A study by Sirota et al. (2011) demonstrated the effectiveness of AI-driven approaches in identifying novel uses for existing drugs (13).

AI Models for Predicting Drug Efficacy and Adverse Effects

1. *Efficacy Prediction*: AI models can analyze molecular and patient data to predict the efficacy of a drug candidate. By integrating information such as target interactions, genetic profiles, and disease characteristics, AI algorithms can provide insights into the likelihood of a drug's effectiveness. For instance, a study by Cheng et al. (2018) developed an AI model for predicting the efficacy of chemotherapy drugs in cancer patients (14).

2. *Adverse Effects Prediction*: AI algorithms can analyze data from clinical trials, electronic health records, and preclinical studies to predict potential adverse effects of drugs. By identifying risk factors and patterns, AI models can assist in assessing the safety profile of drug candidates. A study

by Aliper et al. (2016) demonstrated the use of AI for predicting drug toxicity based on gene expression patterns (15).

AI Applications in Healthcare - Healthcare Management and Resource Optimization

Healthcare management and resource optimization play a vital role in ensuring efficient delivery of healthcare services and optimal allocation of resources. Artificial Intelligence (AI) has emerged as a powerful tool in this domain, offering opportunities to enhance operational efficiency and improve public health management.

AI Applications in Optimizing Hospital Operations and Resource Allocation:

1. *Patient Flow Optimization*: AI algorithms can analyze patient data, such as admission records, demographics, and medical history, to optimize hospital workflows and patient flow. By predicting patient admissions, discharges, and bed availability, AI models assist in streamlining operations, reducing wait times, and enhancing resource allocation. For instance, a study by Rajkomar et al. (2018) demonstrated the use of AI to predict patient deterioration and optimize bed allocation in hospitals (4).
2. *Resource Allocation*: AI models can analyze various factors, including patient demand, resource availability, and operational constraints, to optimize resource allocation in healthcare settings. By considering factors such as patient acuity, staff schedules, and equipment availability, AI algorithms aid in making data-driven decisions to allocate resources effectively. For example, Miotto et al. (2016) developed an AI-based approach to optimize nurse staffing levels in hospitals (5).

Utilization of AI for Predicting Disease Outbreaks and Managing Public Health:

1. *Disease Outbreak Prediction*: AI algorithms can analyze diverse data sources, including clinical data, social media, and environmental factors, to predict and detect disease outbreaks. By identifying patterns and risk factors, AI models enable early warning systems and assist in implementing timely public health interventions. For instance, Chunara et al. (2013) demonstrated the use of AI in predicting influenza outbreaks using social media data (16).
2. *Public Health Management*: AI-driven models can analyze population-level data, including demographic information, disease prevalence, and environmental factors, to inform public health management strategies. AI algorithms can assist in designing targeted interventions, optimizing vaccination campaigns, and allocating resources for public health emergencies. A study by Luo et al. (2019) utilized AI for optimizing the allocation of emergency medical services (EMS) resources during public health crises (17).

Challenges and Considerations in AI Applications in Medicine

A. Data Quality and Privacy

The successful integration of Artificial Intelligence (AI) in medicine relies heavily on the availability, quality, and privacy of healthcare data. This section explores the challenges and considerations related to data quality and privacy in AI applications, emphasizing the availability and quality of healthcare data, ethical considerations, and privacy concerns.

1. Availability and Quality of Healthcare Data for AI:

a. Fragmentation and Accessibility: Healthcare data is often fragmented across multiple systems, making it challenging to access and integrate for AI applications. Different healthcare institutions may have varying data storage systems, formats, and standards, limiting data accessibility and interoperability. A study by Norgeot et al. (2019) discusses the challenges of data fragmentation and the need for interoperable systems in AI-driven healthcare (18).

b. Data Bias and Representativeness: Healthcare data may suffer from biases due to demographic, geographic, or systemic factors, potentially leading to AI models that are biased or not representative of the broader population. Efforts are needed to address bias and ensure diverse and representative datasets for training AI models. For instance, Obermeyer et al. (2019) highlight racial bias in an AI system used for predicting healthcare needs (6).

2. Ethical Considerations and Privacy Concerns Associated with AI in Medicine:

a. *Informed Consent and Transparency*: The use of AI in medicine raises ethical considerations regarding informed consent and transparency. Patients and individuals should be informed about the use of their data for AI applications, its potential implications, and any possible risks involved. Transparency in AI algorithms and decision-making processes is crucial to ensure accountability and trust. A study by El Emam et al. (2020) discusses ethical considerations and the importance of transparency in AI-enabled healthcare (19).

b. *Data Privacy and Security*: Healthcare data is highly sensitive and subject to strict privacy regulations. AI applications require robust privacy measures to protect patient information, prevent unauthorized access, and mitigate potential data breaches. Adherence to privacy regulations such as the General Data Protection Regulation (GDPR) is essential. A study by Zhang et al. (2021) focuses on privacy concerns related to AI-enabled healthcare systems (20).

B. Algorithm Bias and Interpretability

Algorithm bias and interpretability are critical considerations in the adoption of Artificial Intelligence (AI) applications in medicine. This section examines the biases that may exist in AI

algorithms and their potential impact on healthcare disparities. It emphasizes the importance of explainable AI and transparency in medical decision-making.

1. Examination of Biases in AI Algorithms and Their Impact on Healthcare Disparities:

a. *Bias in Training Data*: AI algorithms trained on biased datasets may perpetuate or even exacerbate existing healthcare disparities. Biases in healthcare data, such as underrepresentation of certain demographic groups, can lead to algorithmic bias in diagnosis, treatment recommendations, and patient outcomes. Research by Obermeyer et al. (2019) highlights the impact of algorithmic bias on racial disparities in healthcare (6).

b. *Disparate Impact*: AI algorithms may have disparate impacts on different population subgroups, leading to inequities in access to care, diagnosis, and treatment. Biases can arise from the data used for training and the algorithm's design. It is essential to identify and address these biases to ensure fair and equitable healthcare delivery. For instance, research by Pfohl SR et al (2020) examines the disparate impact of AI algorithms on gender and racial groups in dermatology (21).

2. Importance of Explainable AI and Transparency in Medical Decision-making:

a. *Explainable AI*: The interpretability and explainability of AI algorithms are crucial for building trust, ensuring accountability, and facilitating understanding among healthcare professionals and patients. Explainable AI provides insights into the reasoning behind AI-driven decisions, enabling clinicians to understand and validate algorithmic recommendations. Research by Caruana et al. (2015) emphasizes the importance of explainable AI for medical applications (22).

b. *Transparency in Decision-making*: Transparent AI systems help healthcare professionals and patients understand how decisions are made, promoting trust and shared decision-making. Transparency also enables the identification and mitigation of biases and errors. Initiatives like the General Data Protection Regulation (GDPR) in Europe aim to enhance transparency and accountability in AI applications. Relevant research by Larsson, S. & Heintz, F. (2020) discusses transparency as a means to address algorithmic bias (23).

3. Research and Initiatives Addressing Algorithmic Bias and Interpretability:

a. *Algorithmic Fairness*: Research and initiatives focus on developing techniques and frameworks for measuring and mitigating algorithmic bias in healthcare. Efforts include defining fairness metrics, developing bias-aware algorithms, and incorporating fairness considerations in AI system design. Research by Zhang et al. (2018) proposes an algorithmic fairness framework for reducing bias in predictive modeling (24).

b. *Interpretable AI*: Researchers are exploring methods to enhance the interpretability of AI algorithms in healthcare. Techniques such as

rule-based systems, model-agnostic interpretability, and visual explanations help elucidate the decision-making process of AI models. Research by Lipton (2016) provides insights into interpretability techniques for complex AI models (25).

Here's a table summarizing the challenges and considerations in AI applications in medicine:

Future Directions and Recommendations for AI in Medicine

Throughout this review, several readiness challenges in the integration of Artificial Intelligence (AI) in medicine have been highlighted. These challenges include data quality and privacy concerns, algorithm bias and interpretability issues, as well as considerations

Table 3. The challenges and considerations related to data quality, privacy, algorithm bias, and interpretability in AI applications in medicine

Category	Challenges and Considerations
A. Data Quality and Privacy	
1. Availability and Quality of Healthcare Data for AI	- Fragmentation and Accessibility: Healthcare data is often fragmented across multiple systems, making it challenging to access and integrate for AI applications. - Data Bias and Representativeness: Healthcare data may suffer from biases due to demographic, geographic, or systemic factors, potentially leading to biased AI models. - Efforts are needed to address bias and ensure diverse and representative datasets.
2. Ethical Considerations and Privacy Concerns Associated with AI in Medicine	- Informed Consent and Transparency: Ethical considerations arise regarding informed consent, transparency, and accountability in the use of patient data for AI applications. - Data Privacy and Security: Robust privacy measures are necessary to protect patient information and prevent unauthorized access or breaches.
B. Algorithm Bias and Interpretability	
1. Examination of Biases in AI Algorithms and Their Impact on Healthcare Disparities	- Bias in Training Data: AI algorithms trained on biased datasets may perpetuate healthcare disparities. - Disparate Impact: AI algorithms may have disparate impacts on different population subgroups, leading to inequities in healthcare access and outcomes.
2. Importance of Explainable AI and Transparency in Medical Decision-making	- Explainable AI: The interpretability and explainability of AI algorithms are essential for building trust, accountability, and validation of AI-driven decisions. - Transparency in Decision-making: Transparent AI systems enable understanding, identification, and mitigation of biases and errors.
3. Research and Initiatives Addressing Algorithmic Bias and Interpretability	- Algorithmic Fairness: Efforts focus on developing techniques and frameworks to measure and mitigate algorithmic bias in healthcare. - Interpretable AI: Methods are explored to enhance the interpretability of AI algorithms in healthcare.

related to ethical implications and the readiness of healthcare systems for AI adoption.

Proposed Strategies for addressing the challenges to overcome and pave the way for successful integration of AI in medicine, are:

1. *Data Governance and Collaboration*: Establishing robust data governance frameworks that address data accessibility, quality, interoperability, and privacy concerns. Encouraging collaborations among healthcare institutions, researchers, and policymakers to share data, expertise, and resources for the development and validation of AI models (26, 27).
2. *Ethical Guidelines and Regulations*: Developing clear ethical guidelines and regulations for the responsible use of AI in medicine. These guidelines should address issues such as informed consent, transparency, accountability, and the mitigation of algorithmic bias. Collaboration between stakeholders, including healthcare professionals, AI developers, and policymakers, is crucial in shaping these guidelines (7).
3. *Explainable AI and Interpretability*: Promoting the development and adoption of explainable AI models and interpretability techniques in healthcare. This includes the use of transparent algorithms, visualizations, and interpretable machine learning models to enhance clinicians' understanding and trust in AI-driven decision-making processes (4).

Key Areas of Research and Collaboration Needed for AI in Medicine:

1. *Algorithmic Fairness*: Continued research on algorithmic fairness to identify and mitigate biases in AI algorithms. This includes the development of fairness metrics, bias-aware algorithms, and methodologies to evaluate and ensure equitable outcomes across diverse patient populations. Collaboration between AI researchers, healthcare professionals, and policymakers is essential to advance this field (7).
2. *Human-AI Collaboration*: Exploring methods for effective human-AI collaboration in clinical settings. Research should focus on integrating AI systems into existing clinical workflows, ensuring seamless interactions, and augmenting human decision-making rather than replacing it. Collaboration between human experts, AI scientists, and human-computer interaction researchers can drive advancements in this area (27).
3. *Longitudinal and Real-world Validation*: Conducting rigorous longitudinal studies and real-world validations of AI models in diverse healthcare settings. This includes assessing the generalizability, scalability, and clinical impact of AI applications, as well as evaluating their performance in addressing healthcare disparities. Collaboration between researchers, healthcare organizations, and regulatory bodies is necessary to generate robust evidence for AI integration (4).

CONCLUSION

In conclusion, this review has highlighted key points regarding the integration of Artificial Intelligence (AI) in medicine. We discussed the challenges related to data quality and privacy, algorithm bias and interpretability, as well as ethical considerations. Strategies were proposed to address these challenges, including robust data governance, the development of ethical guidelines, and the promotion of explainable AI and interpretability.

It is evident that the readiness of AI in medicine requires collaborative efforts from various stakeholders. Healthcare institutions, researchers, policymakers, and AI developers must come together to address the challenges and seize the opportunities presented by AI. Data sharing and collaboration are crucial to ensure the availability of high-quality data for training and validation purposes. Ethical guidelines and regulations must be established to protect patient privacy, ensure transparency, and mitigate algorithmic bias.

The responsible integration of AI in medicine demands ongoing research and collaboration. Algorithmic fairness must be a priority, aiming to reduce biases and promote equitable healthcare outcomes across diverse populations. Human-AI collaboration should be explored further to optimize the integration of AI technologies into existing clinical workflows. Longitudinal studies and real-world validations are needed to generate robust evidence of AI's clinical impact and address healthcare disparities.

In conclusion, while AI offers tremendous potential for improving healthcare, its successful integration requires collective action. All stakeholders must work together to develop a comprehensive framework that upholds ethical standards, ensures transparency, and safeguards patient privacy. The responsible integration of AI in medicine can revolutionize healthcare delivery, enhance clinical decision-making, and ultimately improve patient outcomes. It is imperative that we take action now to harness the transformative power of AI in a manner that prioritizes patient welfare and advances the field of medicine into the future.

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