A COMPREHENSIVE AND CRITICAL REVIEW OF ARTIFICIAL INTELLIGENCE (AI) IN PHARMACY, NURSING, LABORATORY, AND MEDICAL FIELDS

Mohammed Saed Al-Harthi[1], Mohammed Talal Al-Sulaimani[1], Fahad Abduallah Al-Zahrani[1], Adel Hulayyil Al-Harthi[1], Sultan Abdullah Al-Harthi[1], Ibrahim Awadh Al-Hamyani[1], Marwa Shalan Al-Dhafeeri[1], Saleh Jabbar Al-Zahrani[2], Saeed Ahmed Al-Zahrani[3], Sabah Abdulrahman Al-Abrash[4], Ashwaq Abdulhamid Al-Ahmadi[5], Shahd Ishag Khan[5], Reyoof Jabr Al-Abbas[6], Saeed Ali Alqahtani[7], Ibrahim Mohammed Al-Helali[8], Hamed Nawar Alharthi[9], Ibrahim Mohammed Dighriri[1*].

Abstract:
Artificial Intelligence (AI) has emerged as a transformative technology with immense potential to revolutionize various healthcare and patient care aspects. This comprehensive review article explores the current state of AI in different medical fields, including pharmacies, nursing, laboratories, and medical practice. This review critically analyzes AI applications, benefits, challenges, and prospects in these domains. The literature search strategy included electronic databases, such as PubMed, Scopus, Web of Science, and Google Scholar, focusing on articles published in English. This review discusses the impact of AI on drug discovery and development, pharmacy operations and inventory management, medication adherence, patient monitoring, clinical decision support, and personalized medicine in the pharmacy field. AI's role in clinical decision support, patient monitoring and predictive analytics, nursing education and training, workflow optimization, and resource allocation is examined in nursing. The laboratory section explores AI's applications of AI in automated experimental design and optimization, data analysis and pattern recognition, robotics and automation, and predictive maintenance and quality control. The medical field section delves into AI's impact of AI on radiology, pathology, and ophthalmology, highlighting the use of convolutional neural networks (CNNs) and deep learning (DL) algorithms in image analysis and disease diagnosis. The review also addresses the challenges and ethical considerations associated with AI's integration of AI in these medical fields, such as data privacy, security, algorithmic biases, and the need for standardization and validation. The prospects of AI in healthcare are discussed, emphasizing the potential of AI to transform healthcare delivery and patient care. The review concludes by acknowledging the need for further research and development to address the challenges and ethical implications associated with its implementation and instilling a sense of optimism about the future of healthcare with AI.

Keywords: Artificial Intelligence, Machine Learning, Deep Learning, Convolutional Neural Networks, Healthcare, Pharmacy, Nursing, Laboratory, Medical Practice.

[1]Department of Pharmaceutical Care Services, King Abdulaziz Specialist Hospital-Taif, Saudi Arabia.
[2]Department of Pharmaceutical Care Services, Qiya General Hospital, Taif, Saudi Arabia.
[3]Department of Pharmaceutical Care Services, ALQARA General Hospital, Al-Baha, Saudi Arabia.
[4]Department of Pharmaceutical Care Services, Taif Children Hospital, Taif, Saudi Arabia.
[5]Department of Pharmaceutical Care Services, Al-Noor Specialist Hospital, Makkah, Saudi Arabia.
[6]Department of Pharmaceutical Care Services, Eradah Mental Health Complex, Jeddah, Saudi Arabia.
[7]Department of Pharmaceutical Care Services, Aseer Central Hospital, Abha, Saudi Arabia.
[8]Department of Pharmacy, Albirk General Hospital, Albirk, Saudi Arabia.
[9]Department of Forensic Center, Forensic Medical Services Center, Al-Baha, Saudi Arabia.

***Corresponding Author**: Ibrahim M. Dighriri
*Department of Pharmaceutical Care Services, King Abdulaziz Specialist Hospital-Taif, Saudi Arabia.

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Introduction:

Artificial Intelligence (AI) is a revolutionary technology with the potential to significantly impact various aspects of healthcare and patient care [1]. As a rapidly growing field of computer science, AI aims to create machines capable of performing tasks that typically require human intelligence [1]. It includes various techniques such as machine learning (ML), DL, and natural language processing (NLP). Large Language Models (LLMs), a specific type of AI algorithm, utilize DL techniques and vast datasets to understand, summarize, generate, and predict new text-based content [2].

The application of AI in medical fields has garnered significant interest owing to its capacity to process vast quantities of data, recognize patterns, and support decision-making [3,4]. AI permeates every aspect of healthcare systems, from complex networks involving purchasers, providers, payers, and patients, by empowering search engines, analyzing data, and offering recommendations [3,4]. ML, the most prevalent form of AI, primarily relies on supervised learning, in which computers are trained using human-determined labels. Deep and adversarial learning involves training unlabeled data to uncover underlying patterns [3,4]. However, current AI thinking lacks understanding of the underlying motivational systems that drive human-like thinking and behavior, such as compassion, and their impact on complex societal systems such as healthcare [5].

Research indicates that AI technologies influence human thought and action and affect how healthcare professionals work and learn [5]. For instance, AI enables more precise imaging and diagnosis [6], enhances the efficiency of clinical screening [6,7], facilitates personalized medicine [7,8], and tailors precision medicine to individual patient needs [8,9].

Compassion, a crucial aspect of healthcare, is a sensitivity to suffering in oneself and others, coupled with a commitment to alleviate and prevent it [10]. It is seen as an evolutionary survival trait of social species, fostering helpful, caring behaviors in an interconnected web of social relationships guided by ethical values and social norms [10]. Compassionate behavior is modeled and learned through interactions such as parenting and teaching [10]. Compassion research shows how the psychology of compassion in the mind impacts the body, improves human health [11], and benefits societies [12]. However, compassion is under-conceptualized and under-explored about AI technologies [13] and how AI technologies might generate or enhance compassion [13].

In healthcare contexts, there is significant interest in compassion for ethical and clinical reasons [9,14]. Compassion is described as a "medical virtue" [15], a "virtuous response" [16], or "intelligent kindness" [16]. It is an expectation in healthcare job recruitment [17], a component of ethical professional practice [18], an indicator of healthcare quality [18], and a dynamic interactional experience that includes motivation, capacity, and connections [18]. Compassionate caregiving involves meaningful actions to alleviate suffering, meet individual needs, and prevent further suffering [19].

AI continues to evolve, and it is essential to ensure that it is developed responsibly and for the benefit of all [20]. The rapid advancement of AI technology presents an opportunity for its application in clinical practice, potentially revolutionizing healthcare services. Documenting and disseminating information regarding AI's role in clinical practice is crucial to equip healthcare providers with the knowledge and tools necessary for effective implementation in patient care. This review article aims to explore the current state of AI in healthcare, its potential benefits, limitations, and challenges, and provide insights into its future development. This review seeks to understand AI's role in healthcare better and facilitate its integration into clinical practice while considering the importance of compassion in healthcare delivery.

Methods:

Study Methods

This comprehensive review aimed to explore the current state of AI in various medical fields, including pharmacy, nursing, laboratory, and medical fields. It used a comprehensive approach to identify, analyze, and synthesize relevant literature.

Literature Search Strategy:

A comprehensive literature search was performed using electronic databases, such as PubMed, Scopus, Web of Science, and Google Scholar. The search strategy included a combination of keywords and Medical Subject Headings terms related to AI, ML, deep learning, and their applications in pharmacy, nursing, laboratory, and medical practice.

Inclusion and Exclusion Criteria:

Studies were included if they met the following criteria:
- Original research articles, systematic reviews, meta-analyses, or case studies
- Focus on AI applications in pharmacy, nursing, laboratory, or medical practice
- Published in peer-reviewed journals
- Written in the English language

Studies were excluded if they were as follows:
- Were editorials, commentaries, or conference abstracts
- Did not focus on AI applications in the specified medical fields
- Were not published in the English language

Study Selection and Data Extraction:
Two independent reviewers screened the titles and abstracts of the identified studies based on inclusion and exclusion criteria. They retrieved full-text articles for those that met the requirements or required further evaluation. Any disagreements with the reviewer were resolved through discussion or consulting a third reviewer.

Data Synthesis and Analysis:
The extracted data were synthesized using a narrative approach, focusing on the key themes and findings related to AI applications in each medical field. The synthesis discusses AI's benefits, challenges, and prospects in pharmacy, nursing, laboratory, and medical practice.

Review:

1. AI in Pharmacy Fields:

1.1 Drug Discovery and Development:
AI has significantly impacted drug discovery and development. ML algorithms can analyze vast amounts of data to identify potential drug targets and predict drug-target interactions [21]. AI-powered tools can also optimize drug design, predict drug properties, and assist in selecting lead compounds [22]. These advancements can accelerate drug discovery, reduce costs, and increase the likelihood of successful drug development.

1.2 Pharmacy Operations and Inventory Management:
AI can streamline pharmacy operations and improve inventory management. Predictive analytics and ML algorithms can forecast medication demand, optimize inventory levels, and prevent stockouts [23]. AI-powered systems can also automate medication ordering, reduce waste, and enhance supply chain efficiency [23]. By optimizing inventory management, pharmacies can reduce costs, improve patient satisfaction, and ensure timely access to medication.

1.3 Medication Adherence and Patient Monitoring:
AI plays a crucial role in improving medication adherence and patient monitoring. ML algorithms can analyze patient data, such as medical records and wearable device data, to predict nonadherence risk and provide personalized interventions [24]. AI-powered chatbots and virtual assistants can engage with patients, offer medication reminders, and answer medication-related queries [25]. These technologies can enhance patient education, medication adherence, and health outcomes.

1.4 Clinical Decision Support:
AI can assist pharmacists in clinical decision-making by providing evidence-based recommendations. NLP techniques can extract relevant information from electronic health records (EHRs) and the scientific literature to support clinical decisions [26]. AI algorithms can detect potential drug interactions, adverse events, and contraindications, helping pharmacists optimize medication therapy and ensure patient safety [27].

1.5 Personalized Medicine:
AI can facilitate the implementation of personalized medicine in pharmacies. AI algorithms can predict individual drug responses and optimize medication regimens by analyzing patient-specific data such as genomic information and clinical history [28]. This approach can lead to more targeted and effective therapies, reducing the risk of adverse drug reactions and improving patient outcomes [29].

1.6 Challenges and Future Prospects:
Despite AI's numerous benefits in pharmacies, some challenges must be addressed. These include data privacy and security concerns, regulatory hurdles, and the need for the robust validation and standardization of AI algorithms [8]. Additionally, integrating AI into pharmacy practices requires significant investment in infrastructure, training, and workforce development. As AI technologies continue to advance, it is crucial to address these challenges and ensure that AI is used responsibly and ethically in the pharmacy [29].

2. AI in Nursing Fields:

2.1 Clinical Decision Support:
AI can assist nurses in clinical decision-making by providing evidence-based recommendations. ML

algorithms can analyze patient data such as vital signs, laboratory results, and medical history to identify patterns and predict patient outcomes [30]. AI-powered clinical decision-support systems can alert nurses to potential complications, suggest appropriate interventions, and support the development of personalized care plans [30]. These systems can enhance the accuracy and efficiency of nursing assessments, improving patient care.

2.2 Patient Monitoring and Predictive Analytics:

AI can facilitate continuous patient monitoring and enable predictive analytics in nursing care. Wearable devices and smart sensors can collect real-time patient data such as heart rate, blood pressure, and oxygen saturation [31]. AI algorithms can analyze these data to detect early signs of deterioration, predict adverse events, and alert nurses to potential risks [31]. Predictive analytics can help nurses proactively intervene, prevent complications, and optimize patient outcomes.

2.3 Nursing Education and Training:

AI can revolutionize nursing education and training by providing personalized learning experiences and simulation-based training. AI-powered adaptive learning platforms can assess individual learning needs, provide tailored content, and adjust the pace of instruction [32]. Virtual and augmented reality technologies can create immersive simulation scenarios, allowing nursing students to practice clinical skills and decision-making in a safe environment [32]. AI-powered chatbots and virtual tutors can provide instant feedback, answer questions, and support self-directed learning [31].

2.4 Workflow Optimization and Resource Allocation:

AI can optimize nursing workflows and resource allocation by analyzing staffing levels, patient acuity, and resource utilization data. Predictive models can forecast patient demand, guide staffing decisions, and ensure optimal nurse-to-patient ratios [32]. AI algorithms can also streamline documentation, automate administrative tasks, and reduce the burden of paperwork on nurses [33]. By optimizing workflows and resource allocation, AI can improve efficiency, minimize nursing workloads, and enhance job satisfaction.

2.5 Challenges and Ethical Considerations:

The integration of AI into nursing practice presents various challenges and ethical considerations. Data privacy, security, and confidentiality are crucial when handling sensitive patient information [34]. Biases in AI algorithms stemming from the data used for training can perpetuate disparities and impact decision-making [35]. Nurses must have the necessary skills and knowledge to interpret AI-generated insights and maintain human oversight [36]. Ethical frameworks and guidelines are needed to address AI's responsible and transparent use in nursing [36].

2.6 Future Prospects:

As AI technologies continue to advance, the future of nursing will likely transform. AI can potentially augment nursing practice, enabling nurses to focus on high-value tasks and patient-centered care [37]. Integrating AI with other technologies, such as robotics and telemedicine, can further enhance nursing care delivery and expand access to healthcare services [38]. However, it is essential to emphasize that AI should be viewed as a complementary tool to support nursing judgment and decision-making rather than replace human nurses [36].

3. AI in Laboratory Fields:

3.1 Automated Experimental Design and Optimization:

AI can assist researchers in designing and optimizing experiments by leveraging ML algorithms. These algorithms can analyze historical experimental data, identify patterns, and suggest optimal conditions [38]. AI-powered tools can also predict experiment outcomes, reducing the need for trial-and-error approaches and saving time and resources [38]. By automating the experimental design and optimization, AI can accelerate the discovery process and enable researchers to focus on more complex tasks.

3.2 Data Analysis and Pattern Recognition:

AI can revolutionize data analysis in laboratory research by enabling the processing of large amounts of complex data. ML algorithms can identify patterns, correlations, and anomalies in large datasets, which may be difficult for humans to detect [38]. DL techniques such as CNNs can analyze images and videos, enabling automated image segmentation, object detection, and classification [39]. AI-powered data analysis can accelerate the discovery of novel insights, facilitate hypothesis generation, and support data-driven decision-making in laboratory research.

3.3 Robotics and Automation:

AI can enhance laboratory automation through the integration of intelligent robotic systems. Robotic platforms powered by AI algorithms can perform repetitive and precise tasks such as sample preparation, liquid handling, and instrument operation [38]. These systems can operate continuously, minimizing human error and increasing throughput [40]. AI-driven robotics can also adapt to changing experimental conditions, optimize workflows, and enable the remote monitoring and control of laboratory processes [40,41].

3.4 Predictive Maintenance and Quality Control:

AI can improve laboratory equipment maintenance and quality control by leveraging predictive analytics. ML algorithms can analyze sensor data from laboratory instruments to predict potential failures, optimize maintenance schedules, and prevent unplanned downtimes [41]. AI-powered quality control systems can detect anomalies, identify trends, and ensure the reliability and reproducibility of experimental results [42]. By implementing predictive maintenance and quality control, laboratories can reduce costs, minimize errors, and maintain high research quality standards.

3.5 Challenges and Ethical Considerations:

The integration of AI into laboratory research presents various challenges and ethical considerations. Data quality, integrity, and security are crucial when dealing with sensitive research data [43]. Biases in AI algorithms stemming from training data or model design can impact the reliability and fairness of the results [3]. Researchers must be trained in the responsible use of AI to understand its limitations and potential pitfalls [43]. Ethical frameworks and guidelines are necessary to address issues such as data privacy, intellectual property, and transparency of AI-driven research [44].

3.6 Future Prospects:

As AI technologies continue to advance, the future of laboratory research is poised for a significant transformation. Integrating AI with other emerging technologies, such as blockchain, the Internet of Things (IoT), and quantum computing, can further enhance the capabilities of intelligent laboratories [44]. AI-powered virtual and augmented reality systems can enable immersive data visualization, remote collaboration, and training in laboratory settings [45]. Developing explainable AI (XAI) techniques can improve interpretability and trust in AI-driven research [46].

4. AI in Medical Fields:

4.1. AI in Radiology

ML algorithms, particularly CNNs, have become a cornerstone in the analysis and interpretation of images, significantly impacting the field of radiology [47]. CNNs are specialized DL algorithms adept at handling visual data, which positions them perfectly for image classification, segmentation, and object detection [47]. They have been employed across various imaging techniques, such as X-rays, CT scans, MRI, and ultrasound, learning from substantial image datasets to discern patterns linked to certain diseases or abnormalities [47]. Once trained, they can swiftly evaluate new images and aid radiologists by providing rapid insights and support in decision-making [47].

CNNs have been instrumental in identifying and categorizing medical anomalies, including tumors, fractures, and cardiovascular diseases, sometimes matching, or surpassing the accuracy of human radiologists [47,48]. These algorithms have facilitated the early diagnosis of conditions such as lung cancer through the sensitive and specific detection of lung nodules on CT scans and have played a critical role in identifying brain tumors on MRI scans [49]. They have also proven effective in musculoskeletal radiology by accurately identifying fractures in X-rays, which is especially valuable in emergency scenarios where prompt diagnosis is essential [49]. Moreover, AI's capability of AI in early cardiovascular disease detection by analyzing cardiac imaging data has been promising, assisting in patient risk stratification and management [47,49].

One of AI's most substantial contributions of AI to radiology is its ability to detect diseases early and minimize diagnostic oversights [49]. AI algorithms excel in pinpointing subtle anomalies that might escape radiologists, particularly in cancer screening, where early detection significantly enhances patient outcomes [50]. AI's role extends to providing a secondary review, offering radiologists an additional evaluation layer to help prevent missed diagnoses and augment the reliability of the diagnostic process [51].

However, integrating AI in radiology has challenges, including the need for extensive, diverse, and accurately annotated datasets to effectively train AI models [52]. These models require a broad spectrum of medical images representing different patient groups, anatomical variations, and pathologies, and these data must be meticulously labeled, a process that requires significant time and resources [53]. Additionally, the " black-box nature of DL models such as CNNs can lead to issues with interpretability and transparency, potentially undermining trust among radiologists and patients [52,53].

To mitigate these issues, the development of XAI is prioritized to shed light on the decision-making processes of AI systems and thereby increase their transparency [53]. Ensuring the use of AI in radiology also involves ethical and regulatory considerations, focusing on patient privacy, data security, and judicious application of AI insights in clinical decisions [53]. To navigate these complexities, collaboration among AI developers, radiologists, and healthcare professionals is crucial to establishing robust and ethical guidelines for AI applications in radiology.

4.2. AI in Pathology

AI has made significant strides in pathology by automating the analysis of histopathological images and enhancing the precision of disease diagnoses, notably in cancer cases [54,55]. Histopathology is essential for diagnosing and predicting cancer, but the traditional manual examination of tissue samples is tedious and prone to variability and requires considerable expertise [55]. Incorporating deep learning, especially CNNs, in analyzing these histopathological images paves the way for more consistent and efficient diagnostic practices [55]. Successfully applied CNNs have shown adeptness in categorizing and dissecting images to facilitate recognizing and evaluating cancers, such as those affecting the breast, lungs, and prostate [56]. AI tools are transforming the role of pathologists by screening slides and pinpointing regions for further examination [56]. They provide quantifiable insights into tumor specifics, including their grade and stage, thus easing pathologists' burden, and honing the diagnostic process for cancer [55,56].

AI's capability to detect and measure subtle cellular and morphological features that may be invisible to the human eye is another substantial benefit in pathology [54]. Trained by extensive collections of digital slides, AI algorithms can uncover minute anomalies and complex patterns, aiding in detecting uncommon or nuanced cancer types that may necessitate tailored treatment plans [55]. Moreover, AI's consistent and objective evaluations of histological attributes can diminish the subjective nature of manual analysis. These quantitative contributions are vital for uniform pathology reporting and crafting more precise prognostic and predictive frameworks [55].

Nonetheless, AI's integration into pathology is not without hurdles. Developing robust and clinically validated algorithms that can navigate the intricacies of histopathological images is a significant challenge [57]. Pathological specimens are inherently diverse; thus, AI must be trained on various datasets to ensure its applicability across different clinical settings and patient groups [55].

Validating AI algorithms is fundamental to confirming their efficacy and practical utility, necessitating comprehensive testing against independent datasets and real-world clinical trials [55]. Standardization of the validation and benchmarking processes is also crucial for gaining the trust and acceptance of the pathology community [57]. In addition, there is an urgent need for standardized imaging acquisition and processing protocols. The quality of digital pathology slides is critical to the performance of AI systems, necessitating clear guidelines for slide preparation, scanning, and data stewardship to guarantee consistent and reliable AI analyses [54]. Successful integration of AI into pathology requires a collaborative effort involving AI experts, pathologists, and IT professionals. As AI systems are adopted, considerations regarding data privacy, security, and ethical patient data usage remain paramount to ensure their implementation in pathology practice.

4.3. AI in Ophthalmology:

In ophthalmology, AI is increasingly utilized for diagnosing and managing prevalent eye conditions, including diabetic retinopathy, glaucoma, and age-related macular degeneration (AMD) [58]. These diseases are among the top contributors to vision loss globally, making early detection and prompt treatment vital for preserving sight. AI, mainly through DL and CNNs, is adept at interpreting various ophthalmic images such as color fundus photos, OCT scans, and visual fields [58]. These AI-driven tools aid in automatically identifying and categorizing the signs of eye diseases, thus supporting ophthalmologists in crafting precise diagnostic and therapeutic strategies [58].

The ability of AI to recognize and categorize diabetic retinopathy from fundus images is notable, allowing for the swift referral of patients to eye care specialists [59]. AI's utility extends to OCT scan evaluation, offering detailed assessments of retinal layers and detecting changes relevant to the diagnosis and follow-up of glaucoma and AMD [59]. Automated retinal imaging and OCT scan analysis are prime AI applications in ophthalmology [60,61]. Retinal imaging is indispensable for diagnosing and managing eye diseases, offering insights into the condition of the retina and other ocular components [60,61].

AI algorithms can handle tasks such as segmenting anatomical features, spotting lesions, and measuring pathological elements in retinal images [60]. DL models are particularly effective in automatically identifying and outlining the optic disc and retinal blood vessels in fundus photographs, which aids in assessing factors such as the cup-to-disc ratio for glaucoma diagnosis [62]. CT scan analysis also benefits from AI. DL algorithms can segment retinal layers, identify abnormal features, and calculate retinal thickness, which is crucial for managing AMD and diabetic macular edema [60,61].

AI is promising to enhance eye disease screening programs and bolster telemedicine in ophthalmology. It can facilitate swift and cost-effective screenings for eye diseases, which is particularly valuable in areas with limited resources [62,63]. Such AI-assisted screenings could detect individuals at risk for severe eye conditions early on, promoting timely intervention [63,64]. For diseases such as diabetic retinopathy, early action is critical for preventing or slowing vision loss [63,64].

AI has also expanded the reach of telemedicine in ophthalmology, allowing remote diagnosis and treatment of eye diseases. By analyzing images from community clinics or mobile units, ophthalmologists can offer their expertise to patients from afar, increasing the accessibility of eye care, especially in underserved locations [60,65]. AI models can be influenced by training data characteristics such as demographic makeup, disease occurrence, and imaging techniques [66]. Training and validating AI on diverse datasets that reflect a spectrum of patient demographics, age groups, and disease stages is essential to address this. Neglecting this can result in AI tools that underperform or misguide when applied to demographics not well-represented in the training data [66].

Moreover, AI algorithms require thorough clinical validation before being adopted in practice [62]. Their evaluation should extend beyond diagnostic accuracy to consider their effects on patient outcomes, cost implications, and how they fit into current clinical processes [62]. Maintaining the reliability and robustness of AI tools also necessitates continuous monitoring and updating to adapt to shifts in imaging technology, disease patterns, and clinical standards [66]. Establishing standardized development, validation, and implementation guidelines for AI in ophthalmology is crucial for its safe and beneficial integration into healthcare [62,66].

Conclusion:

AI is poised to revolutionize various aspects of healthcare, from drug discovery and nursing education to medical imaging analysis and disease diagnosis. The applications of AI span across pharmacy, nursing, laboratory, and medical fields, showcasing its immense potential to streamline operations, augment clinical decision-making, and improve patient outcomes. Despite the remarkable progress, challenges such as data privacy, algorithmic biases, and ethical considerations must be addressed to ensure the responsible and transparent implementation of AI in healthcare settings. Collaboration among AI developers, healthcare professionals, and regulatory bodies is crucial for establishing robust guidelines and fostering trust in AI technologies. As AI continues to evolve, its integration with emerging technologies like quantum computing and explainable AI will further enhance its capabilities, paving the way for a future where AI serves as a powerful tool to transform healthcare delivery and provide personalized, compassionate care to patients worldwide.

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The authors declare no conflicts of interest.

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