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Review Article

The Role and Impact of Artificial Intelligence in Shaping Resident Doctor Education

Witthawin Sae-Lee

Department of Anesthesiology, Faculty of Medicine Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

Abstract

Artificial intelligence (AI) holds immense potential to transform resident doctor education by offering personalized, adaptive learning experiences and enhancing clinical skill development. Drawing from a literature search of key academic databases for articles published between 2018 and 2024, this review explores the current applications, benefits, challenges, and future directions of AI integration into residency training programs. AI facilitates structured curriculum design, enabling customized pathways based on individual resident needs and performance data. It enhances mentorship and monitoring through virtual tutors, improved accessibility, and data-rich workplace-based assessments, while complementing traditional human oversight. AI-driven simulations provide safe environments for procedural practice with immediate, objective feedback, showing promise in specialties like radiology, dermatology, and ophthalmology. However, significant challenges remain, including the need for robust validation, addressing risks of over-reliance that may hinder critical thinking, managing medicolegal concerns, ensuring faculty development, and meeting infrastructure requirements. Concerns about AI's impact on the job market also influence residents. Successfully leveraging AI requires addressing these challenges through further research, developing ethical guidelines, and integrating AI literacy throughout medical training to prepare future physicians effectively.

Keywords: Artificial intelligence, Medical education, Residency training, Curriculum design, Clinical simulation

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Corresponding Author:
witthawin.sae@mahidol.ac.th

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Introduction

Artificial intelligence (AI) represents a multidisciplinary domain within computer science, dedicated to creating systems that emulate or surpass human cognitive functions. These systems excel in visual perception, speech recognition, natural language processing, and complex decision-making.[1] The application of AI to medical education, in particular, holds immense potential for transforming resident training and improving patient care. The primary objective of AI research is to develop sophisticated models capable of processing vast datasets, learning from experiences, and adapting to new situations, thereby exceeding traditional human capabilities.[2]

This transformative impact is already evident across various medical domains. For instance, AI-powered diagnostic tools are enhancing clinical decision support for residents, predicting patient outcomes, and suggesting treatment protocols in real-time. In surgical training, AI-enhanced simulations allow residents to practice complex procedures in a safe and controlled environment, receiving immediate feedback on their technique.[3-5] These applications demonstrate the potential of AI to not only improve patient care but also to revolutionize the way residents learn and develop essential skills. While these

Clinical Decision Support Systems (CDSS) hold great promise, their successful integration into clinical workflows also necessitates careful consideration of factors such as credibility and usability.[4] Beyond diagnostics, AI is revolutionizing fields like drug discovery and surgical precision.[6, 7]

As AI continues to integrate into medical practice, medical education must evolve. Training programs must prepare future physicians to work effectively and ethically with AI. In particular, AI offers personalized learning experiences tailored to each resident's needs and learning style, accelerating knowledge acquisition and professional development. Current applications of AI in medical education include learning support through individualized feedback and guided learning pathways, which improve educational outcomes while reducing costs. However, challenges remain, such as addressing the technical complexities of developing AI applications and ensuring their effectiveness in sensitive areas like examinations. To meet these challenges, systematic curricular reforms should integrate AI into medical training, enabling future physicians to maximize AI's potential while maintaining a human-centered approach to care.[8, 9]

The integration of AI into medical education raises critical questions about the role of educators, the balance between human and machine input, and ethical considerations. AI offers opportunities for personalized learning, improved simulations, and data-driven assessments, but also necessitates a shift in traditional teaching methods. Educators must acquire a foundational understanding of AI to align their curricula with emerging healthcare demands while addressing challenges such as ethical use and maintaining human oversight in education.[10]

Despite the growing adoption of AI in clinical practice, its integration into residency training programs remains in its early stages, with limited consensus on best practices and significant gaps in the literature. This review explores the current state, benefits, challenges, and future directions of AI in medical resident education. It examines successful AI implementations, discusses curriculum design implications, and addresses ethical considerations. By doing so, it aims to contribute to the dialogue on AI's role in shaping the future of medical education and provide insights for educators, administrators, and policymakers.

Methodology

Search Strategy and Data Sources

This review was conducted through a systematic search of prominent academic databases, including PubMed and Scopus, to identify relevant literature. The search was performed between October 2024 and December 2024. The following keywords and their combinations were used: ’Artificial Intelligence’, ’Machine Learning’, ’Residency Training’, 'Graduate Medical Education’, ’Curriculum Design’, ’Clinical Simulation’, and ‘Physician Training’. The search was limited to peer-reviewed articles, including original research, reviews, and commentaries, published in English between January 2018 and December 2024 to ensure the review captured the most current research in this rapidly evolving field.

Study Selection and Eligibility Criteria

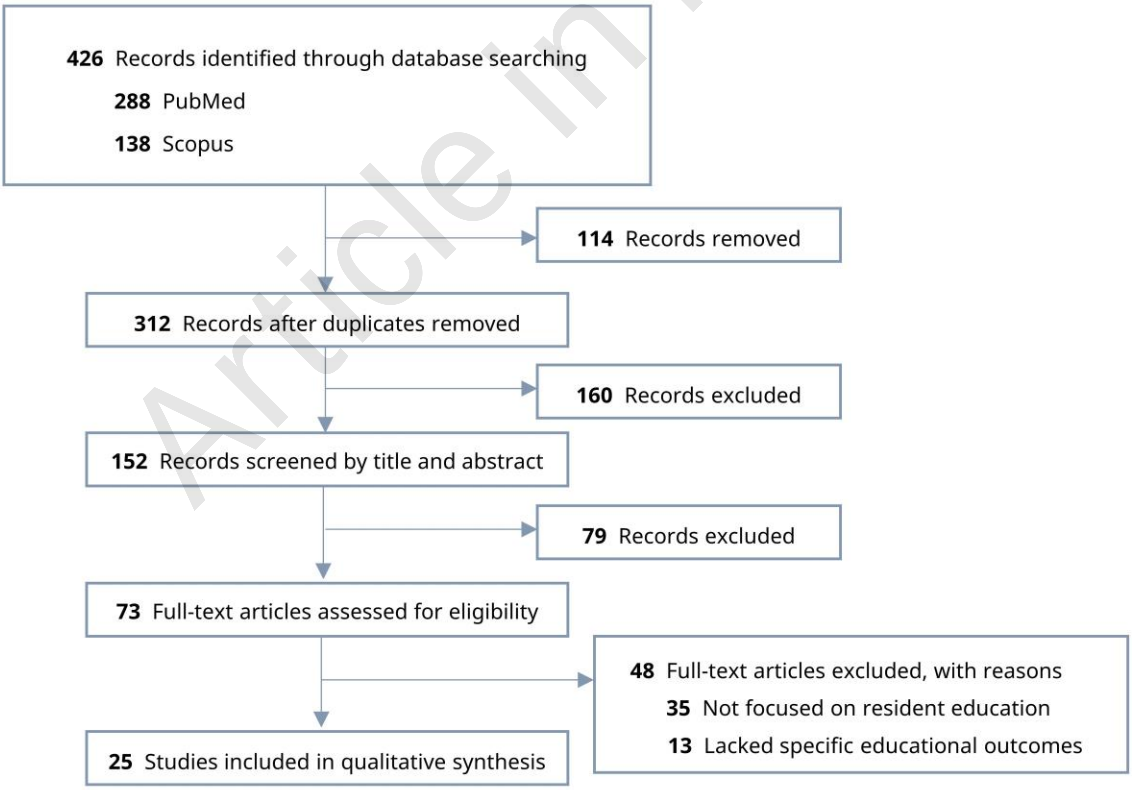
The study selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Initially, titles and abstracts were screened for relevance. Subsequently, the full texts of potentially eligible articles were thoroughly reviewed to determine if they met the final inclusion criteria. For the purpose of this review, a resident doctor is defined as a physician who has graduated from medical school and is undergoing a formal, supervised postgraduate training program (ie, residency) to acquire specialized competence in a specific medical field before being licensed for independent practice. The entire selection process is illustrated in the flow diagram (Figure 1).

Inclusion criteria were 1) peer-reviewed articles published in English; 2) studies focusing on the application, integration, or impact of AI in postgraduate medical education or residency training programs; and 3) articles discussing curriculum design, mentorship, skill development, assessment, or challenges related to AI in resident education.

Exclusion criteria were 1) articles where the primary focus was on undergraduate medical education or continuing medical education for practicing physicians not in a training program; 2) studies centered exclusively on AI in clinical practice without a clear link to resident education or training; 3) editorials, letters, or opinion pieces that did not provide a substantial review of evidence or original data; and 4) articles not available in full-text format.

The final synthesis included 25 articles that met all eligibility criteria. Data from these articles were thematically analyzed to identify key themes, benefits, challenges, and future directions regarding the role of AI in shaping resident doctor education.

Figure 1. PRISMA Flow Diagram Illustrating the Study Selection Process



Review Contents

The literature on the integration of AI into resident education is rapidly expanding, covering several key themes from curriculum design and skill development to assessment and resident perceptions. To provide a clear overview of the foundational evidence discussed in this review, a selection of key, representative studies were presented (Table 1). These articles have been chosen to highlight the most impactful findings and innovative approaches across the primary domains of AI's role in shaping the future of medical training.

Curriculum Design and Educational Frameworks Integration

Integrating AI into residency training is best achieved through a structured approach that maximizes learning outcomes and ensures effective implementation. This framework should include assembling a team of AI experts, assessing the current knowledge level of residents, setting learning objectives, and aligning these with effective teaching strategies. The continuous evaluation and refinement of the curriculum will ensure its relevance and efficacy.[11] To illustrate the practical application of such structured curricula, well-constructed programs, like a 3-day intensive curriculum, have demonstrated effectiveness. These programs, featuring didactic lectures, hands-on workshops, and group discussions, have proven to boost residents' understanding and confidence in using AI technologies, particularly in fields like radiology. Similarly, a 3-week AI workshop integrated into academic sessions showed measurable improvement in AI competency.[12]

Building upon the benefits of structured curricula and interactive learning formats, recent studies highlight the transformative potential of AI in enabling personalized, interactive learning experiences.[13] Through advanced algorithmic analysis of learner data, AI systems can generate pedagogically optimized materials that correspond to individual trainees' cognitive preferences, learning modalities, and competency levels. This evidence-based approach facilitates enhanced comprehension of complex medical concepts while promoting data-driven clinical decision-making. Furthermore, research indicates that AI-enabled adaptive learning platforms can dynamically adjust to residents' developmental progression, thereby improving both diagnostic accuracy and measurable learning outcomes.[14] AI systems can also be adapted to different levels of expertise, offering tailored experiences for both novice and experienced clinicians. This adaptability ensures that residents receive training that is relevant to their current level of proficiency while still challenging them appropriately as they advance.[15]

Expanding on the concept of individualized learning, AI education should also be continuous, starting in medical school and extending through residency and professional practice. This continuous approach ensures that residents build upon a solid foundation and stay up to date as AI evolves.[16] Furthermore, beyond individual learning, AI is transforming traditional educational models by enabling a more universal and interconnected approach to learning.[17] AI facilitates this by providing access to vast databases of medical knowledge and connecting learners with experts and peers across geographical boundaries. To solidify these theoretical and broader learning approaches, practical applications are essential. For example, the use of AI tools like computer-aided diagnosis (CAD) systems gives residents the chance to practice interpreting clinical images and other data independently while reinforcing real-world diagnostic skills.[18]

AI-Enhanced Monitoring and Mentorship

Addressing the persistent challenges within medical education, particularly in providing consistent and effective mentorship and monitoring, AI offers promising solutions. The traditional paradigms of mentorship and performance monitoring in residency training programs often face limitations, including variations in mentor availability, subjectivity in assessments, and logistical constraints in providing timely feedback. However, the implementation of AI-driven mentorship solutions has emerged as a valuable approach to enhance these critical aspects of resident education. Through the deployment of virtual intelligent tutors and conversational agents, AI systems can provide personalized guidance and support continuous learning development, making mentorship more accessible and responsive to individual needs.[19] These AI-enabled virtual tutors can function as supplementary coaches, delivering real-time feedback during critical training phases, ensuring the maintenance of consistent and constructive feedback mechanisms, particularly when human mentors are unavailable.[20] The potential of AI extends beyond virtual tutors, encompassing various tools and approaches to augment and transform mentorship and monitoring in residency training.

Furthermore, AI technology has proven instrumental in addressing longstanding logistical challenges within medical education. By mitigating constraints related to time and geographical limitations, AI systems facilitate seamless mentor-mentee interactions regardless of physical location.[19] This enhanced accessibility has particular significance in contemporary medical education, where distributed learning environments and remote training scenarios have become increasingly prevalent. The literature emphasizes that these technological solutions not only improve the efficiency of mentorship delivery but also contribute to more equitable access to educational resources across diverse training settings.

AI's role in monitoring and assessment has demonstrated particular efficacy through the implementation of workplace-based assessments (WBAs) and diverse evaluation tools. These systems generate rich datasets that facilitate both formative feedback and summative entrustment decisions, ensuring residents meet required competencies while providing valuable insights into their developmental progression.[21] For example, AI can analyze WBA data to identify specific areas where residents consistently struggle, allowing program directors to tailor teaching modules to address these weaknesses. The systematic collection and analysis of performance data enable educational programs to identify trends, adjust teaching strategies, and optimize learning outcomes more effectively than traditional assessment methods alone.

Recent studies have highlighted the importance of integrating AI-enhanced monitoring systems with traditional educational frameworks. This integration enables a more nuanced understanding of resident performance through multidimensional assessment approaches, combining objective performance metrics with subjective evaluations from human mentors.[20] For instance, AI can track a resident's performance on simulated surgeries, providing data on precision and efficiency, while human mentors can assess their communication skills and bedside manner. The synergistic relationship between AI-driven monitoring and human oversight ensures that both quantitative and qualitative aspects of resident development are adequately addressed, leading to more comprehensive and effective educational outcomes.

However, scholars emphasize the importance of maintaining appropriate balance in AI implementation. While AI-enhanced monitoring and mentorship systems offer substantial benefits, they should complement rather than replace traditional human mentorship roles. The literature suggests that optimal outcomes are achieved when AI systems are strategically deployed to augment existing mentorship structures, providing additional layers of support and assessment while preserving the essential human elements of medical education.[19]

Enhanced Learning and Skill Development

Current AI studies in residency training focus largely on simulation settings and the development of technical skills, particularly targeting skill classification and performance assessment. However, larger sample sizes and more balanced data are needed to strengthen these studies.[22] AI-driven simulation-based training enables residents to practice and refine their diagnostic capabilities in controlled environments, leading to enhanced diagnostic accuracy and improved preparedness for clinical scenarios.[14, 23] The technology also provides automated and immediate feedback, which is particularly beneficial as many residents report receiving minimal corrective feedback on their performance. This real-time feedback enhances formative evaluations without entirely replacing traditional feedback mechanisms.[24]

Recent research demonstrates that AI implementation has shown considerable promise in enhancing diagnostic accuracy across various medical specialties. In dermatology, AI tools provide real-time diagnostic support and simulate rare conditions that are often underrepresented in traditional training settings, while virtual reality integration enables residents to practice technical procedures safely through feedback on crucial metrics such as instrument placement and pressure application.[25] This technological integration has particular significance in addressing educational gaps and enhancing surgical skill development through immersive learning experiences.[26] Natural language processing and machine learning applications have revolutionized resident assessment by offering more objective evaluations of clinical competencies, analyzing written and verbal responses, and tracking skill development with unprecedented precision.[27]

In radiation oncology, AI has transformed traditional didactic approaches by supporting flipped learning methodologies and enhancing case-based learning through curated, de-identified clinical vignettes. The technology provides real-time feedback for critical skills such as contouring and treatment planning, helping residents develop intuitive capabilities in patient assessment and procedural accuracy. Notably, AI-powered simulations have become particularly valuable in areas like brachytherapy training, where practical exposure opportunities have declined.[28, 29]

However, scholars emphasize critical considerations regarding AI integration in clinical practice. The literature cautions that excessive dependence on AI systems could potentially compromise the development of critical thinking and diagnostic capabilities among medical trainees. For example, if residents rely solely on AI-generated diagnoses without independently evaluating patient data, their ability to develop sound clinical judgment may be hindered. The maintenance of AI system efficacy necessitates regular updates and rigorous validation to prevent the perpetuation of incorrect diagnostic patterns. Furthermore, successful implementation requires substantial technological infrastructure investment and continuous system optimization to ensure sustained effectiveness.[30] Additionally, logistical challenges and the need for multi-institutional databases must be addressed to optimize AI's impact on medical education. The integration of AI into clinical settings provides realistic healthcare environments that help improve critical thinking and clinical reasoning skills, especially in fields where trainees encounter a wide range of clinical challenges.[31] This integration enhances the practical application of theoretical knowledge while maintaining the crucial balance between technological assistance and independent clinical judgment.

Empirical evidence supports the effectiveness of AI-integrated learning approaches in specialty training. In ophthalmology, AI-assisted training systems have demonstrated significant improvements in residents' diagnostic capabilities, with studies showing higher post-lecture test scores compared to traditional learning methods, particularly in specialized areas such as pathologic myopia identification and classification.[32] Furthermore, structured AI curricula like AI-RADS have proven effective in building residents' confidence and competence in understanding and applying AI technologies in clinical practice. These programs successfully bridge the gap between theoretical knowledge and practical application through a combination of didactic lectures and interactive learning experiences.[33]

Challenges and Considerations

Integrating AI into residency training presents several significant challenges and considerations that must be addressed to ensure successful implementation. One notable issue is the reliance on small sample sizes and the focus on senior residents in pilot studies, since AI applications in residency programs are still in their infancy. There is currently no consensus on the optimal timing for introducing AI decision support systems (AI-DSS) into the curriculum, highlighting the need for further research to guide these critical decisions.[16]

Additionally, the use of AI in surgical training raises important medicolegal concerns, particularly regarding high-stakes decision-making and the risk of patient harm stemming from erroneous AI recommendations. It is essential to examine how flawed algorithms might impact residents' careers and their progression through training, as these implications could have lasting effects on both individual practitioners and patient safety.[34]

Moreover, there is a pressing need for specialized AI educational content within residency programs. Residents must be equipped with the skills to interpret imaging studies and understand AI tools before they can effectively apply them in clinical practice. Hands-on laboratories and structured lecture series have been identified as effective educational formats for this purpose.[18, 35] Despite many residents expressing support for AI and machine learning (ML) education, continuous courses throughout residency are necessary to ensure proficiency in utilizing these tools effectively.[35]

Furthermore, the potential impact of AI on job markets is influencing residency selection. Medical students are increasingly concerned that advancements in AI may render certain specialties, such as diagnostic radiology, obsolete, which can affect their career decisions.[36] Addressing these concerns through transparent discussions about the evolving role of AI in medicine will be crucial for attracting future talent to all specialties.

Table 1. Summary of Representative Studies on AI in Resident Education

Author, Year	Specialty/Domain	AI Application/Tool	Key Findings/Outcomes
Curriculum Design and Educational Frameworks			
Hu et al,[12] 2023	Diagnostic Radiology	AI Training Workshop	Demonstrates that a short, intensive workshop format can measurably improve residents' confidence and understanding of AI concepts.
Lindqwister et al,[33] 2021	Radiology	AI-RADS Curriculum	Proposes a structured, standardized curriculum (AI-RADS) that successfully enhances residents' competence in applying AI technologies.
Skill Development and Simulation			
Bilgic et al,[22] 2022	Surgical Education	Scoping Review	Found that AI in surgery primarily focuses on skill classification and performance assessment, providing objective metrics for technical skills.
Desseauve et al,[14] 2024	Obstetrics	ChatGPT	Evaluated how residents interact with large language models, highlighting the need to develop skills for effectively and safely using AI in clinical queries.
Fang et al,[32] 2022	Ophthalmology	Pathologic Myopia ID System	Showed that an AI-assisted training system was significantly more effective than traditional lectures for improving residents' diagnostic accuracy.
Kwon et al,[28] 2023	Radiation Oncology	AI-Empowered Education	AI tools can provide real-time, objective feedback for critical skills like tumor contouring and treatment planning, enhancing procedural accuracy.
Challenges and Resident Perceptions			
Atalay et al,[36] 2023	Diagnostic Radiology	Survey	Showed that medical students' career decisions are being influenced by concerns over AI's potential impact on the job market in certain specialties.
Salastekar et al,[35] 2023	Radiology	Multi-institutional Survey	Revealed that a majority of residents are supportive of AI education and desire continuous training integrated throughout their residency.

Abbreviation: AI, artificial intelligence.

Discussion

The integration of AI in residency training programs represents a significant paradigm shift in medical education, with growing evidence supporting its effectiveness across multiple specialties. This literature review reveals several key themes and implications that warrant careful consideration for future development and implementation.

Educational Effectiveness and Innovation

Recent studies provide compelling evidence of the superior effectiveness of AI-integrated learning approaches compared to traditional methods. For instance, in ophthalmology residency programs, AI-assisted training systems have demonstrated statistically significant improvements in diagnostic accuracy and skill development, demonstrated by higher post-lecture test scores in specialized areas such as pathologic myopia identification and classification.[32] Similarly, structured AI curricula like AI-RADS have successfully enhanced residents' confidence and competency in utilizing AI technologies in radiology, bridging the gap between theoretical knowledge and practical application.[33] These findings strongly suggest that AI integration, when properly designed and implemented, can accelerate the learning curve, improve educational outcomes, and better prepare residents for the demands of modern medical practice.

Adaptability and Implementation Challenges

The experiences documented during the COVID-19 pandemic, particularly in the Toronto neurology residency program, highlight the critical importance of adaptability in medical education systems.[37] While this adaptation was driven by necessity, it clearly demonstrates the latent potential for technological integration, including AI, in residency training. However, the implementation of AI systems faces several challenges that must be addressed proactively. These include substantial infrastructure requirements, significant cost considerations related to software and hardware, and the imperative for comprehensive faculty development to ensure educators are equipped to effectively integrate AI into their teaching. The successful integration of AI in radiology residency programs, which has involved dedicated resources and faculty training, provides a valuable model for addressing these challenges while simultaneously maintaining and enhancing educational quality.[38]

Ethical Considerations of Data Privacy and Algorithmic Bias

A crucial aspect of integrating AI into resident education involves navigating the complex ethical landscape, particularly concerning data privacy and algorithmic bias. The use of AI tools necessitates the collection and analysis of vast amounts of sensitive data, including patient information and resident performance metrics, raising significant data privacy and security concerns.[39] It is imperative that robust safeguards and clear protocols are established to govern data handling, ensuring compliance with regulations like the Health Insurance Portability and Accountability Act (HIPAA) and maintaining patient and resident confidentiality.[39,40] Furthermore, the issue of algorithmic bias poses a substantial threat to equitable medical education.[41] Since AI systems learn from existing data, they are susceptible to inheriting and amplifying biases present in that data, which can lead to disparities in resident assessments. For instance, if an AI is trained on data that disproportionately represents certain demographics, it may develop biases that disadvantage underrepresented groups.[41] This can manifest as skewed performance evaluations or the perpetuation of stereotypes in diagnostic training modules.[42] Addressing this requires a multi-faceted approach, including the use of diverse and representative datasets, regular audits of AI algorithms for bias, and the development of transparent, explainable AI systems. By prioritizing data privacy and actively mitigating algorithmic bias, medical education programs can foster a more just and effective learning environment for all residents.

Implications of the Study

The findings of this review carry significant implications for various stakeholders within the medical education ecosystem. For educators and program directors, the integration of AI necessitates a paradigm shift from traditional teaching models to a more dynamic, data-driven approach. Curricula must be redesigned to not only include AI literacy but also to leverage AI tools for personalized learning pathways and objective assessments. This requires substantial investment in faculty development to equip educators with the skills to guide residents in a technologically advanced environment.

For policymakers and healthcare institutions, this review underscores the need for strategic planning and resource allocation. The successful implementation of AI in residency training is contingent upon robust technological infrastructure, the development of ethical guidelines, and the establishment of standards for the validation and oversight of AI tools. Proactive policies are required to address medicolegal concerns and ensure that the use of AI enhances, rather than compromises, patient safety and quality of care.

Finally, for resident doctors, the message is clear: AI is poised to become an integral component of medical practice. Rather than a threat to their future roles, it should be viewed as a powerful tool that can augment their skills and improve efficiency. Early and continuous exposure to AI technologies during training is crucial for developing the competence and critical appraisal skills necessary to work effectively alongside these systems, ensuring they can harness the benefits while being mindful of the potential pitfalls.

Limitations of the Study

This review has several limitations. Its findings are constrained by the rapid pace of AI development, a potential publication bias towards positive results, and significant heterogeneity among the included studies. Our search restrictions to English-language databases may have also excluded relevant research. A primary limitation is the literature's focus on short-term educational metrics over long-term clinical competency and patient outcomes. Finally, this review's scope intentionally focused on direct clinical training, excluding the significant roles of AI in resident research and administrative management. Future longitudinal, multi-institutional studies are needed to address these gaps.

Conclusions

This review highlights AI's potential to transform resident education through personalized learning and enhanced skills. However, challenges remain. Studies often have small sample sizes. Medicolegal concerns exist, especially in surgical training. Residency programs need specialized AI content and continuous training. Medical students worry about AI's impact on job markets. Moving forward, larger studies, ethical guidelines, and proactive discussions about AI's role in medicine are needed to ensure it benefits both residents and patients.

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Author Contributions:
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Visualization: Witthawin Sae-Lee
Writing – Original Draft: Witthawin Sae-Lee
Writing – Review & Editing: Witthawin Sae-Lee

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