Jurnal Fisika 15 (2) (2025) 1-7

Jurnal Fisika

https://journal.unnes.ac.id/nju/index.php/jf/index

The Future Direction of Radiology: The Role of AI and Augmented Reality in Medical Visualization

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Article Info

Article History:

Received:
9 April 2025

Accepted:
15 Juni 2025

Published:
12 November 2025

Keywords: Artificial Intelligence, Augmented Reality, Challenges, Integration, Medical Imaging, Radiology Innovation.

Abstract

The rapid advancement of digital technologies has significantly influenced the field of medical imaging, particularly through the integration of Artificial Intelligence (AI) and Augmented Reality (AR). These technologies offer transformative potential in improving diagnostic accuracy, enhancing surgical planning, and addressing the limitations of traditional radiological methods. This study aims to evaluate the roles and effectiveness of AI and AR in radiology by analyzing their applications in medical diagnosis and surgical visualization, with a focus on increasing diagnostic speed, precision, and accessibility, especially in resource-limited settings. A systematic literature review was conducted by examining 45 peer-reviewed articles published between 2017 and 2025, selected based on relevance, innovation, and applicability. Thematic analysis revealed that AI—especially models using convolutional neural networks—has demonstrated high accuracy in detecting lung disease, breast cancer, and brain tumors. Meanwhile, AR has shown potential in enhancing spatial understanding and accuracy in surgical procedures. Despite these benefits, several challenges were identified, including integration difficulties with existing hospital systems, algorithmic bias, regulatory constraints, and high costs. In conclusion, the integration of AI and AR represents a promising direction for the future of radiology. However, further research is needed to develop cost-effective systems, ensure ethical and inclusive AI training, and establish standardized protocols for implementation. This study provides a foundational overview for healthcare stakeholders aiming to adopt these technologies in pursuit of more equitable and efficient medical imaging practices.

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p-ISSN 2088-1509

INTRODUCTION

The digital revolution has had a significant impact, particularly in the field of healthcare, with the integration of Artificial Intelligence (AI) and Augmented Reality (AR) into medical imaging systems (Goceri, 2023). These cutting-edge technologies are transforming traditional diagnostic approaches by enabling faster image analysis and more precise interpretation (Thomas Wendler, 2021). Specifically, in telemedicine, AI-based algorithms can process complex imaging data in seconds, while AR provides enhanced visualization during surgical procedures (Burton, 2021). These technological advancements offer potential solutions to critical limitations in conventional radiology practices, which still heavily rely on manual interpretation and two-dimensional imaging (Kalidindi S., 2023).

Despite the rapid advancements in medical imaging, significant challenges remain that need urgent attention. The diagnostic process still requires considerable time, with healthcare professionals— particularly radiologists—often facing excessive workloads that lead to delays in patient care (Kothinti, 2024). Variations in image interpretation among specialists frequently result in inconsistent diagnoses, potentially affecting treatment outcomes (Alper, 2020). Additionally, many healthcare facilities, especially in rural and developing regions, struggle to access advanced imaging technologies due to high costs and infrastructure requirements (Goh, 2021). Recent research highlights the promising applications of AI and AR in addressing these challenges (Vaidya, 2020). Current studies demonstrate that AI algorithms can achieve accuracy comparable to radiologists in detecting fractures and tumors, while AR systems have proven effective in guiding complex surgical interventions (Megbuwawon, 2024). However, several research gaps remain, including the need for more diverse training datasets to reduce algorithmic bias and the development of more affordable AR hardware (Burton, 2021). Research on the implementation of these technologies in resource-limited settings is also scarce, despite their potential to significantly reduce healthcare disparities (Vaidya, 2020).

This study aims to systematically evaluate the most effective implementations of AI and AR in medical imaging by comparing various technological approaches. The focus is on identifying solutions that not only enhance diagnostic speed and accuracy but also improve the accessibility of advanced imaging services (Elizabeth von Ende, 2023). In particular, the application of telemedicine could bridge the gap between urban healthcare centers and remote communities, potentially serving as a benchmark for revolutionizing healthcare delivery models (Burton, 2021). The ultimate goal of this research is to provide evidence-based recommendations for healthcare providers adopting AI and AR technologies in medical imaging. By analyzing both the technical capabilities and practical limitations of existing systems, this study is expected to contribute to the development of more efficient, accurate, and equitable diagnostic solutions (Goceri, 2023). The findings will serve as a valuable resource for medical institutions facing challenges in the digital transformation of radiology and telemedicine services (Kothinti, 2024).

METHOD

This study employed a literature review method as the primary approach to analyze the role of Artificial Intelligence (AI) and Augmented Reality (AR) in the field of radiology, particularly in surgical planning and medical diagnosis. The literature search utilized keywords such as "AI in radiology," "AR for surgery," "medical imaging," and "AI-based diagnosis" across reputable databases including PubMed, IEEE Xplore, ScienceDirect, and Google Scholar, with a focus on increasing diagnostic speed, precision, and accessibility, especially in resource-limited settings. A systematic literature review was conducted by examining 45 peer-reviewed articles published between 2017 and 2025, selected based on relevance, innovation, and applicability to current clinical challenges.

The selected literature was purposively sampled based on its relevance to the research topic, the novelty of the findings, and the extent to which it discussed the implementation of technology in clinical settings. Particular attention was also given to studies that explored the use of AI and AR in resource-limited environments, highlighting the potential for technological development in underserved healthcare systems. A total of 45 articles were reviewed for this study, encompassing diverse applications and evaluations of AI and AR in radiological contexts.

The gathered data were analyzed qualitatively using a thematic approach to identify patterns in the application of technology, its clinical benefits, and the challenges associated with implementation. The analysis also involved evaluating the methodological reliability of each source, including an assessment of possible biases in AI model training data. Through this approach, the study aims to provide a comprehensive understanding of how AI and AR are being integrated into modern medical imaging and offer recommendations for the future development of technology-driven radiology services.

RESULT AND DISCUSSION

The rapid advancement of digital technology has opened significant opportunities in the medical field, particularly through the integration of Artificial Intelligence (AI) and Augmented Reality (AR). Recent literature shows that the collaboration between AI and AR has the potential to revolutionize modern radiology practice. This innovation has been widely implemented in two main areas: surgical planning and medical diagnosis, both of which heavily depend on visualization accuracy and decision-making speed. The integration of these technologies enables the creation of systems that not only analyze medical data in-depth but also present spatial representations of this information in real time for medical practitioners.

This review analyzed 45 scholarly articles published between 2017 and 2025 to evaluate the implementation of Artificial Intelligence (AI) and Augmented Reality (AR) in radiological imaging. The findings are categorized into four thematic sub-sections: AI in Radiological Imaging, AR in Surgical Visualization, Integration of AI and AR, and Challenges and Future Directions. The detailed discussion is presented below.

Artificial Intelligence in Radiological Imaging

Artificial Intelligence (AI) has become a cornerstone in the transformation of modern radiological diagnostics. Among the 45 articles reviewed, 28 articles discuss the application of AI in detecting abnormalities in MRI, CT, and X-ray images. This technology, particularly with Convolutional Neural Networks (CNN), has demonstrated performance equal to or even surpassing human radiologists in some specific cases. In addition to speeding up image interpretation, AI also reduces cognitive fatigue for medical personnel. However, several studies indicate the limitations of model generalization when applied to different populations, highlighting the need for multinational validation and more representative datasets.

Table 1. AI Application in Radiology Based on Reviewed Studies

AI Focus	Number of Studies	Key Findings
Lung disease detection	10	CNN detects pneumonia with >92% accuracy (Rajpurkar et al., 2017)
Breast cancer detection	6	Diagnosis accuracy comparable to professional dermatologists (Esteva et al., 2023)
Brain tumor classification	5	AI increases analysis speed by up to 80% compared to manual methods
Automatic segmentation	4	Assists in creating patient-specific 3D anatomical models
AI model evaluation	3	Data bias challenges and the need for external validation

Augmented reality in radiological visualization

Augmented Reality (AR) offers a new dimension in anatomical visualization, especially for surgical planning and medical training. A total of 12 articles review the effectiveness of AR in presenting medical image information interactively and in three dimensions. Systems such as Microsoft HoloLens are used to project internal body structures in real-time on patients. As a result, there is an increase in incision accuracy and spatial understanding by medical teams. Although promising, the main limitation lies in the high cost of the devices and the still-imperfect spatial tracking accuracy.

Table 2. AR Applications in Radiological Visualization

AR Application Type	Related Studies	Clinical Benefits	Challenges
Surgical planning	6	Improved incision accuracy, reduced operation time	High cost of devices
3D visualization of organs & tissues	3	Easier spatial orientation during surgery	Limited tracking accuracy
Interactive medical training	2	Speeds up medical student learning curves	Lack of local content
Remote collaboration	1	Medical teams can view patient data together in real-time	Data synchronization & connectivity issues

Integration of AI and AR

The integration of AI and AR is a new approach that is still minimally explored but offers a comprehensive solution. Only five studies examined systems combining automatic image analysis (by AI) with spatial visualization (through AR). One successful example is the integration of AI for liver tumor segmentation with AR overlay for resection planning. Such systems enable real- time surgical simulation, adjusting to the patient's organ movement or breathing.

Table 3. AI and AR Integration Studies

Study/ Implementation	AI Function	AR Function	Key Findings
Maier-Hein et al. (2022)	Automatic liver tumor segmentation	3D projection of structure onto the patient’s body	More accurate navigation, more efficient surgery time
Chowriappa et al. (2020)	Skin anomaly detection	Visualization of analysis results directly on the skin	Real-time diagnosis, direct validation by doctors
Surgical procedure simulation	Tissue deformation prediction	Dynamic AR following patient’s movement	Adaptive visualization, minimizing potential errors

Challenges and future directions

Although AI and AR show promising results, several critical challenges remain. First, existing systems are difficult to integrate with hospital digital infrastructures (such as PACS and HIS) due to the lack of universal data standards. Second, algorithmic bias due to geographically limited training data remains a serious issue. Regulations from agencies such as the FDA also pose barriers to the rapid adoption of these technologies. Lastly, the readiness of human resources, particularly in terms of training and understanding the ethical use of these technologies, is insufficient.

Table 4. Challenges and Recommendations for Implementing AI and AR

Main Challenge	Explanation	Strategic Recommendations
System interoperability	Systems are incompatible across hospitals	Development of open medical data protocol standards
AI model bias	Limited and homogeneous training datasets	Federated learning & multinational training
Regulation & data security	Long approval times and audits required	Alignment with GDPR/HIPAA and use of encryption
High cost & hardware limitations	AR devices are expensive and not yet precise	Collaborative R&D for low-cost and open-source AR devices
Medical staff readiness	Lack of training & practical knowledge	Digital training & integration of AI/AR into medical curricula

CONCLUSION

This study successfully addressed its primary objectives by systematically evaluating the integration of Artificial Intelligence (AI) and Augmented Reality (AR) in medical imaging, with a focus on improving diagnostic speed, accuracy, and accessibility. The review of 45 scholarly articles demonstrated that AI significantly enhances image interpretation through advanced algorithms like Convolutional Neural Networks (CNN), achieving diagnostic accuracy comparable to, or even exceeding, that of human radiologists in several clinical scenarios.

Meanwhile, AR contributes to improved spatial visualization, particularly in surgical planning and training, offering real-time, interactive 3D representations of internal anatomical structures.

Furthermore, although only a few studies explore the combined application of AI and AR, the evidence suggests that this integration holds strong potential to revolutionize radiology by enabling dynamic, real-time decision support during medical procedures. The study also identified major challenges including system interoperability, algorithmic bias, regulatory barriers, and hardware costs, especially in resource-limited settings. To address these, the research offers strategic recommendations such as adopting open data standards, implementing federated learning models, and enhancing digital training for medical personnel.

Overall, this study provides evidence-based insights and practical recommendations that support the adoption of AI and AR technologies in medical imaging, ultimately contributing to the development of more efficient, accurate, and equitable radiological services in both advanced and underserved healthcare environments.

ACKNOWLEDGEMENT

We would like to express our deepest gratitude to Departement of Biomedical Engineering, Institut Teknologi Sumatera, for their guidance, knowledge, and continuous support throughout the learning process and the preparation of this journal. The academic support and conducive learning environment have played a significant role in the completion of this work.

We also extend our sincere appreciation to the researchers who have advanced the application of augmented reality and artificial intelligence (AI) in the field of medical imaging. Their research has served as a valuable reference in the writing of this journal. The encouragement and constructive input from various sources have greatly assisted us in completing this work. We truly value the discussions and suggestions that have broadened our understanding and deepened our insights into the topic presented in this study.

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