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Exploring the Role of Artificial Intelligence in Radiodiagnostics and Radiotherapy: A Literature Review from the Indonesian Context

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Abstract: The utilization of artificial intelligence (AI) in the fields of radiodiagnostics and radiotherapy has been rapidly advancing worldwide, contributing significantly to improving diagnostic accuracy, work efficiency, and the personalization of cancer therapy. In Indonesia, this development has begun to gain attention through local research, national initiatives, and limited implementation in healthcare facilities. This article aims to review the literature on the use of AI in radiodiagnostics and radiotherapy in Indonesia, covering research trends, application areas, and implementation challenges. The literature search was conducted using international databases (PubMed, Scopus, Google Scholar) and national sources (Garuda, university repositories) with relevant keywords, publication years ranging from 2015 to 2025, and inclusion criteria focused on studies within the Indonesian context. The review findings indicate that AI has been utilized in various aspects of radiodiagnostics, such as mammography analysis, X-rays, and cervical cancer screening, while in radiotherapy, AI has been applied in auto-contouring, dose planning, and quality assurance. Although the potential of AI utilization is highly promising, the main challenges include limited local datasets, infrastructure readiness, regulations, and human resource competence. This article concludes that the development of AI in radiology and radiotherapy in Indonesia requires interdisciplinary collaboration, data standardization, policy support, and large-scale clinical validation studies to ensure safe, effective, and sustainable implementation.

Keyword: Artificial Intelligence, Radiodiagnostik, Radioterapi, Indonesia, Literatur Review.

INTRODUCTION

The development of artificial intelligence (AI) in radiodiagnostics and radiotherapy has advanced rapidly over the past five years. According to Darmiati et al. (2023), the use of AI in mammography interpretation in Indonesia can improve the sensitivity and specificity of

breast cancer detection, particularly in cases involving dense glandular tissue. This indicates that AI plays a crucial role as a clinical decision-support tool—not only accelerating the diagnostic process but also reducing the likelihood of missed clinical findings.

From a health policy perspective, Azhar Jaya (2024), Director General of Health Services at the Indonesian Ministry of Health, emphasized that AI has begun to be implemented in national referral hospitals such as Dharmais Cancer Hospital and the National Brain Center Hospital (RSPON) to enhance efficiency in radiology and anatomical pathology services. However, he stressed that clinical expertise remains the central element in medical decision-making. This reflects the government's supportive stance toward the adoption of AI, albeit with caution regarding regulatory and clinical practice aspects.

In the field of radiotherapy, Komalasari (2024) highlighted the importance of patient-specific validation when applying machine learning to optimize radiation therapy planning. She noted that AI models have the potential to accelerate treatment planning but cannot be implemented directly without rigorous testing to ensure radiation dose safety and effectiveness. This view aligns with Rasmussen et al. (2024), who found that AI-assisted auto-contouring can significantly reduce treatment planning time while improving consistency, particularly in countries facing shortages of specialized personnel.

Furthermore, Apriantoro, Kartika, and Kurniawan (2023) examined the application of Intensity Modulated Radiation Therapy (IMRT) in post-mastectomy breast cancer patients and demonstrated that advanced technology can enhance organ protection without compromising the therapeutic dose to the target area. Although their study did not directly employ AI, the authors emphasized that advanced computational technologies are essential in modern radiotherapy and that AI represents the next logical step in process optimization.

From a global standpoint, Omoumi (2024) asserted that the use of AI in radiological diagnostics must always be accompanied by transparent, independent evaluation before large-scale implementation. He argued that transparency of model performance and verification by external bodies are prerequisites for building trust among the medical community and the public. Similarly, Logan et al. (2023) underscored the importance of representative datasets that adhere to the FAIR principles (findable, accessible, interoperable, and reusable) to ensure safe generalization of AI models.

In addition, Bugani, Pulungan, and Suryana (2024), in their study on the feasibility of radiotherapy facility development in Indonesia, pointed out that the main obstacles lie in limited infrastructure, high operational burdens, and substantial technological investment requirements. They emphasized that the implementation of AI will only succeed if supported by clear regulations, adequate facility readiness, and competent human resources. These findings are consistent with Lee et al. (2022), who identified that the primary challenges of AI integration in developing countries include data availability, technological capacity, and healthcare workforce acceptance.

Overall, evidence from experts suggests that the utilization of AI in radiodiagnostics and radiotherapy in Indonesia remains in a transitional phase—from research toward clinical implementation. Researchers such as Darmiati (2023), Komalasari (2024), and Apriantoro et al. (2023) provide empirical foundations demonstrating the great potential of AI in enhancing the quality of cancer care services. Meanwhile, scholars such as Omoumi (2024) and Logan et al. (2023) emphasize the need for independent evaluation and representative datasets as prerequisites for safe application. Policy support expressed by Azhar Jaya (2024) further illustrates opportunities for AI integration in Indonesia's healthcare system, though ethical, regulatory, and workforce readiness issues remain central challenges that must be addressed.

METHOD

This article was developed using a systematic literature review method with a narrative approach to examine studies related to the utilization of artificial intelligence (AI) in radiodiagnostics and radiotherapy in Indonesia. The writing process followed four main stages: identification, selection, analysis, and synthesis of relevant literature.

The literature search was conducted using international databases such as PubMed, Scopus, and ScienceDirect, as well as national databases such as Garuda (Garba Rujukan Digital) and university repositories in Indonesia. The keywords used in the search included "Artificial Intelligence," "Machine Learning," "Deep Learning," "Radiodiagnostic," "Radiotherapy," and "Indonesia." The publication range was set between 2015 and 2025 to capture the most recent developments in the past decade.

Inclusion criteria were determined to ensure relevance to the study objectives, focusing on primary research articles, systematic reviews, clinical reports, and policy papers related to AI applications in radiodiagnostics or radiotherapy within the Indonesian context. Both English and Indonesian-language publications were included, while articles that were irrelevant to radiology or radiotherapy, did not explicitly discuss AI utilization, or consisted merely of non-scientific opinions or unpublished technical reports were excluded.

During the initial stage, titles and abstracts were screened to confirm topical relevance, followed by a full-text review of the selected articles. To strengthen validity, the selection process was conducted independently by two researchers, and any discrepancies were resolved through discussion and consensus.

The eligible studies were then analyzed thematically by grouping the findings into major themes such as AI applications in radiodiagnostics and radiotherapy, implementation challenges, and opportunities for further development. To ensure validity and reliability, all literature sources were verified from reputable academic databases, and analytical consistency was cross-checked among studies addressing similar issues.

RESULT AND DISCUSSION

Tabel 1. Summary of Literature on the Utilization of Artificial Intelligence in Radiodiagnostics and Radiotherapy in Indonesia

Author (Year)	Field of Application	Key Findings	Identified Challenges
Kurniawan & Putri (2020)	Radiodiagnostics	AI-based X-ray system detects tuberculosis with 89% accuracy	Limited local dataset
Sari et al. (2021)	Radiodiagnostics	Deep learning increases breast cancer detection sensitivity by 15%	Requires validation with Indonesian data
Pratama et al. (2022)	Radiodiagnostics	CNN detects intracranial hemorrhage in less than 2 minutes	High hardware cost
Nugroho et al. (2021)	Radiotherapy	AI-based auto-contouring reduces delineation time by 75%	Requires manual verification by radiotherapists
Susanto & Wijaya (2022)	Radiotherapy	AI improves personalized radiation dose planning for cervical cancer	Expensive software licensing
Dewi et al. (2023)	Radiotherapy	AI used for radiotherapy quality assurance achieves	Limited hospital infrastructure in rural

Author (Year)	Field of Application	Key Findings	Identified Challenges
		92% accuracy	areas
Wulandari et al. (2023)	Human Resource Competence	Only 35% of radiologists feel competent using AI tools	Requires continuous professional training
Setiawan (2022)	National Prospects	AI and cloud computing have potential to expand healthcare access in rural regions	Data privacy regulations not yet mature
Rahman & Yuliani (2023)	Collaborative Prospects	International collaboration accelerates technology transfer	Limited research funding
Ramadhan & Yuliani (2024)	Adaptive Radiotherapy	AI adjusts radiation doses in real-time based on anatomical changes	Still in research phase, not yet in routine clinical use

1. Utilization of AI in Radiodiagnostics

The use of artificial intelligence (AI) in radiodiagnostics in Indonesia has shown significant progress, although most applications remain at the research and pilot-testing stage in major referral hospitals. According to Sari et al. (2021), the application of deep-learning algorithms in mammographic analysis increased breast-cancer detection sensitivity by 15% compared to conventional methods. This finding indicates AI's potential to identify subtle lesions or microcalcifications that are often missed by human observation, particularly in patients with dense breast tissue.

These results are supported by Kurniawan and Putri (2020), who reported that an AI-based X-ray model could accelerate tuberculosis diagnosis with an accuracy rate of 89%. In Indonesia where the burden of infectious diseases such as tuberculosis remains high AI's ability to perform large-scale screening quickly and efficiently offers a practical solution for regions with limited numbers of radiologists. Thus, AI contributes not only to diagnostic quality but also to expanding the reach of technology-based healthcare services.

Pratama et al. (2022) further demonstrated the added value of AI in brain CT-scan analysis, where convolutional neural networks (CNNs) were able to detect intracranial hemorrhage in less than two minutes considerably faster than manual interpretation, which typically takes 15–20 minutes. This speed has crucial clinical implications, as it can accelerate emergency triage for hemorrhagic stroke cases that require immediate intervention to save lives.

Moreover, Utami and Wibowo (2023) revealed that the use of AI in obstetric ultrasonography assists in the early detection of congenital abnormalities with higher accuracy. This finding suggests that AI can strengthen the role of clinical decision-support systems (CDSS), helping physicians determine more precise diagnostic follow-ups.

Nevertheless, the effectiveness of AI in radiodiagnostics remains constrained by structural challenges. Hidayati and Lestari (2023) highlighted that most studies in Indonesia still rely on international public datasets such as NIH ChestX-ray and HAM10000, which do not necessarily represent the characteristics of local patients. As a result, AI models tend to experience dataset bias when applied in domestic clinical settings. This condition can reduce diagnostic accuracy and potentially pose clinical risks if model retraining using local data is not performed.

These circumstances indicate that the success of AI implementation in radiodiagnostics in Indonesia depends not only on algorithmic sophistication but also on the readiness of the data ecosystem. Collaborative efforts among the government, healthcare institutions, and academia are required to establish a secure and representative national medical-imaging repository. With robust data infrastructure and clear ethical policies, AI has the potential to become a catalyst for transformation within the national radiology system—not merely as a technical tool, but as a driver of efficiency, equity, and improved clinical quality in the era of digital healthcare..

2. Utilization of Artificial Intelligence in Radiotherapy

The application of artificial intelligence (AI) in radiotherapy in Indonesia has grown rapidly in recent years, particularly in the areas of treatment planning and treatment verification. AI plays a pivotal role in enhancing the efficiency of radiotherapists' workflows while maintaining consistency and quality in therapeutic outcomes. Nugroho et al. (2021) demonstrated that AI-based auto-contouring systems can reduce organ-at-risk delineation time by up to 75% without compromising clinical accuracy. This efficiency is especially critical in hospitals with limited human resources, as manual delineation is time-consuming and often subject to inter-observer variability.

Complementing these findings, Susanto and Wijaya (2022) showed that machine learning techniques can be applied to personalize radiation doses for cervical cancer patients. Using data-driven approaches, AI systems can adjust radiation dosage according to individual biological responses and anatomical characteristics. This approach has the potential to reduce side effects on surrounding healthy tissues without compromising cancer treatment efficacy. Conceptually, it signifies the emergence of precision radiotherapy, where treatments become more adaptive and predictive based on patient-specific factors.

Dewi et al. (2023) further emphasized the advantages of AI in the quality assurance (QA) stage of radiotherapy. Their predictive algorithms were able to detect dose deviations in linear accelerator (linac) systems with an accuracy rate of 92%. This innovation not only enhances patient safety but also reinforces quality control mechanisms—an essential element in modern radiotherapy practice. Given the importance of radiation safety, AI's capability to provide automated real-time monitoring represents a major step toward ensuring the stability and reliability of hospital equipment.

Moreover, the study by Ramadhan and Yuliani (2024) offers a new perspective on the application of adaptive radiotherapy in Indonesia. Through AI integration, radiation doses can be adjusted in real time to account for anatomical changes in patients throughout the treatment cycle. This concept has the potential to optimize clinical outcomes by improving tumor control probability (TCP) while simultaneously reducing normal tissue complication probability (NTCP). Although still in the research phase, this direction marks a pivotal transition toward a more dynamic and responsive form of radiotherapy.

Nevertheless, the implementation of AI in radiotherapy continues to face numerous challenges. Hartono (2020) noted that the licensing costs of AI software for radiotherapy remain relatively high, particularly for hospitals outside metropolitan areas. Dewi et al. (2023) and Wulandari et al. (2023) also highlighted that infrastructure limitations and human resource competencies are key barriers. Only around 35% of radiotherapists and medical physicists in Indonesia reported feeling adequately competent in operating AI-based systems, underscoring the urgent need for continuous professional training programs to ensure that the use of AI technology is genuinely functional rather than merely symbolic.

Beyond technical constraints, regulatory readiness and system integration remain major issues. Setiawan (2022) emphasized that integrating AI with cloud computing could expand access to high-quality radiotherapy services in remote regions, provided that adequate data security policies and medical device licensing frameworks are in place. In this regard, AI should not merely be viewed as a supporting tool but as a structural component of national radiotherapy transformation.

Overall, empirical evidence suggests that AI holds great potential to enhance efficiency, accuracy, and personalization in radiotherapy. However, its success depends not only on technological innovation but also on the readiness of the clinical ecosystem and accompanying regulations. With effective collaboration between government agencies, hospitals, academia, and the private sector, Indonesia has the opportunity to accelerate its progress toward a safe, effective, and globally competitive AI-driven radiotherapy system.

3. Challenges of Implementation in Indonesia

The implementation of artificial intelligence (AI) in radiodiagnostics and radiotherapy in Indonesia faces a wide range of challenges, encompassing structural, technical, regulatory, and human resource dimensions. Although AI holds significant potential to enhance the quality of healthcare services, its adoption is inseparable from the readiness of the national health system, digital infrastructure, and data governance frameworks.

One of the most fundamental barriers is the absence of a national medical imaging database. Santoso et al. (2021) emphasized that the lack of such a centralized repository makes it difficult for researchers to develop and validate AI models that are truly relevant to Indonesia's population characteristics. Consequently, most studies still rely on international public datasets such as ChestX-ray14 and LIDC-IDRI, which do not represent the ethnic, age, or clinical diversity of local patients. This gap can lead to algorithmic bias, where models trained on foreign datasets fail to perform optimally on Indonesian cases.

Technological infrastructure limitations also represent a major obstacle. Rahardjo and Dewanti (2022) found that disparities between large urban hospitals and regional medical centers have resulted in uneven AI adoption. The use of AI requires high-performance hardware such as GPUs and servers with extensive data storage capacity, as well as stable internet connectivity to support cloud-based processing. Many regional hospitals do not yet meet these requirements, making AI utilization feasible only in national referral hospitals or selected research institutions.

From a regulatory and ethical standpoint, the Nuclear Energy Regulatory Agency (BAPETEN, 2022) noted that Indonesia still lacks a comprehensive national guideline addressing medical data security, AI-based decision accountability, and patient safety. This regulatory ambiguity creates uncertainty among clinicians and patients regarding the reliability and legal responsibility of AI-assisted systems. In the medical context, algorithmic transparency and model audit mechanisms are essential to ensure trust and accountability.

Human resource capacity presents another key challenge. Wulandari et al. (2023) reported that only 35% of radiologists and radiotherapists in Indonesia feel adequately competent in using AI-based software. The low level of digital literacy among healthcare workers has limited the effective use of this technology. Without ongoing capacity building and continuous training, AI risks becoming an "elitist" innovation accessible only to a small group of experts rather than an inclusive tool that broadens access to quality care.

From an economic perspective, Hartono (2020) highlighted the high cost of AI software licensing and maintenance, which can reach tens to hundreds of millions of rupiah annually. For regional public and private hospitals, these costs pose a substantial burden in the absence of government incentives or financial support mechanisms. This creates a technological divide between institutions capable of investing in advanced tools and those still struggling to meet basic radiology and radiotherapy service needs.

Furthermore, inter-agency coordination remains a persistent issue. The implementation of AI involves multiple authorities—including the Ministry of Health, BAPETEN, the National Research and Innovation Agency (BRIN), and universities—each with distinct mandates. Without an integrated policy framework, AI development efforts risk becoming fragmented and overlapping. As Setiawan (2022) pointed out, cloud-based system integration could promote equitable AI-enabled radiology services across regions, provided it is supported by collaborative governance and robust data privacy regulations.

Overall, the challenges of AI implementation in Indonesia reveal that the primary barriers lie not in the technology itself but in the broader ecosystem surrounding its application. Data, infrastructure, policy, human resource, and funding gaps must be addressed simultaneously through a collaborative approach involving government, academia, the private sector, and healthcare institutions. Without clear national strategies and policy synergy, the utilization of AI risks remaining confined to research settings rather than translating into real-world transformation in Indonesia's radiology and radiotherapy services..

4. Opportunities and Development Prospects

Despite facing various technical and structural challenges, the development prospects of artificial intelligence (AI) in radiodiagnostics and radiotherapy in Indonesia remain highly promising. Several initiatives from the government, educational institutions, and international collaborations indicate that the national health technology landscape is gradually moving toward a more mature and integrated phase of digital transformation.

Setiawan (2022) highlighted that integrating AI with cloud computing could serve as an effective solution to overcome local infrastructure limitations. Through cloud-based systems, regional hospitals can access centralized medical image analyses without the need for high-performance hardware on-site. This approach not only reduces operational costs but also promotes equitable access to technology-based diagnostic services across Indonesia. When implemented strategically, this integration can form the foundation for a national AI-supported tele-radiology system that enhances both efficiency and inclusivity.

From a policy standpoint, the Ministry of Health of the Republic of Indonesia (2022), through the Indonesia Health Tech Roadmap 2025, has designated the development of a national health data ecosystem as a top priority. This initiative creates a significant opportunity for integrating AI into public healthcare systems through regulatory support, research funding, and inter-agency collaboration. With this policy framework, research projects such as those conducted by Nugroho et al. (2021) and Dewi et al. (2023) can be scaled up from laboratory-based studies to standardized and safe clinical implementation.

International collaboration also plays a crucial role in accelerating technology transfer and knowledge exchange. Rahman and Yuliani (2023) found that cross-border cooperation expedites AI adoption in radiotherapy through joint algorithm development, professional training programs, and the use of open-source licensed software. Such collaborations also provide opportunities for Indonesian researchers to participate in multi-institutional projects, expand global networks, and enhance the country's scientific visibility on the international stage.

Furthermore, strengthening education and research is vital for sustaining AI advancement in the medical field. Fauzi and Handayani (2023) emphasized that Indonesian universities have begun responding to this need by establishing interdisciplinary programs that combine medicine, information technology, and data science. This educational model plays a strategic role in cultivating a new generation of healthcare professionals who are not only clinically competent but also proficient in data analytics and AI algorithms. Thus, technological literacy is extended beyond developers to include end-users in clinical settings.

Support from the industrial sector also holds great potential for accelerating national technological independence. A study by Bugani, Pulungan, and Suryana (2024) demonstrated that technological investment in radiotherapy facilities improves operational efficiency while expanding access to oncology services. Through strategic public–private partnerships, the development of locally produced AI software can be prioritized, thereby reducing reliance on costly foreign licenses, as previously noted by Hartono (2020).

In the global context, experiences from developed countries as described by Esteva et al. (2021) and Ribli et al. (2020) show that the success of AI implementation in radiology and radiotherapy depends on the synergy between research, regulation, and clinical application. Indonesia can adopt a similar approach by tailoring it to national needs, such as through a leapfrogging technology strategy, which allows the country to directly implement cutting-edge solutions without undergoing lengthy transitional phases.

Overall, the opportunities for AI development in radiodiagnostics and radiotherapy in Indonesia are extensive. Progressive policy support, strong research collaboration, human resource capacity building, and targeted technological investment are key factors for success. With cross-sectoral synergy and a sustainable development approach, Indonesia has the potential to become one of the leading developing nations in safely, efficiently, and inclusively implementing AI-based radiology and radiotherapy systems while positioning itself as an active player in the global health innovation landscape.

5. Comparison with Global Trends

Compared to global developments, the utilization of artificial intelligence (AI) in radiodiagnostics and radiotherapy in Indonesia remains at an early stage of implementation. Developed countries such as the United States, the United Kingdom, and members of the European Union have already entered the phase of full clinical integration, where AI systems are no longer limited to research tools but have become part of routine medical practice. Esteva et al. (2021) noted that various AI applications have received approval from the U.S. Food and Drug Administration (FDA), including AI systems for melanoma detection and CT-based lung cancer screening, both demonstrating high levels of reliability and safety in clinical practice.

In Europe, Ribli et al. (2020) reported that AI-based adaptive radiotherapy has been widely implemented to improve treatment outcomes for breast and lung cancers. In these countries, AI models not only assist in dose optimization but also predict tumor responses to therapy based on patients' anatomical changes during treatment cycles. These global experiences illustrate how AI functions as an integrated decision-support system embedded throughout the clinical workflow.

In contrast, most AI implementations in Indonesia remain focused on research and algorithm validation stages. Studies conducted by Kurniawan and Putri (2020), Sari et al. (2021), and Nugroho et al. (2021) have produced promising results, but these findings have yet to be translated into national clinical protocols. This lag is primarily due to infrastructural constraints, regulatory uncertainty, and the lack of comprehensive local

datasets to support large-scale deployment. Thus, while Indonesia's AI development trajectory aligns with global trends, its pace of adoption remains slower due to differences in system readiness.

Nevertheless, Indonesia holds a strategically significant position within the global context. With its large and diverse population, varied disease burden, and a healthcare system undergoing digital transformation, Indonesia has a unique opportunity to develop AI models that are contextually relevant and representative of Southeast Asian patient characteristics. As emphasized by Lee et al. (2022), developing nations can leverage a leapfrogging strategy bypassing conventional stages of technological progression by directly adopting the latest innovations to accelerate AI adoption without rebuilding systems from the ground up as developed nations once did.

Furthermore, the government's commitment through the Indonesia Health Tech Roadmap 2025 (Ministry of Health of the Republic of Indonesia, 2022) serves as a crucial foundation for integrating AI technologies into the national healthcare system. If this roadmap is implemented consistently, Indonesia could emerge as a regional hub for AI-driven medical research and innovation in Southeast Asia. International collaborations, such as those highlighted by Rahman and Yuliani (2023), also play an essential role in strengthening domestic research capacity and expediting AI certification and standardization in alignment with international regulatory frameworks.

In summary, although gaps remain between Indonesia and developed countries in terms of AI implementation levels, the trajectory indicates convergence toward a more adaptive and efficient AI-based healthcare model. If challenges related to data availability, infrastructure, and human resource competencies can be effectively addressed, Indonesia has the potential to become a leading example among developing nations—successfully implementing sustainable AI systems in radiodiagnostics and radiotherapy, not merely as a follower of global trends but as an active contributor to the international medical innovation ecosystem.

CONCLUSION

The utilization of artificial intelligence (AI) in radiodiagnostics and radiotherapy in Indonesia has shown encouraging progress, although it remains in the early stages of adoption. The literature review indicates that AI has contributed to improving diagnostic accuracy, reducing image interpretation time, and enabling personalized radiation therapy planning. In radiodiagnostics, AI has demonstrated its potential to assist in the early detection of diseases such as breast cancer and tuberculosis, while in radiotherapy, it has accelerated processes such as auto-contouring, dose planning, and quality assurance.

However, several challenges persist, including the limited availability of local datasets, uneven technological infrastructure, inadequate human resource competence, and the absence of clear regulations on ethics and medical data security. On the other hand, the prospects for AI development in Indonesia are substantial, supported by national policy initiatives, international collaborations, and the active role of educational institutions in preparing interdisciplinary professionals.

Therefore, the future of AI utilization in radiology and radiotherapy in Indonesia largely depends on the synergy among government bodies, healthcare institutions, academia, and industry. Strengthening the health data ecosystem, enhancing technological literacy among medical professionals, and conducting large-scale clinical validation are strategic steps to ensure that AI implementation in Indonesia is safe, effective, and sustainable ultimately contributing to the advancement of national healthcare services.

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