International Journal of Innovative Research and Scientific Studies, 8(7) 2025, pages: 645-655

IJIRSS International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Artificial intelligence in radiology: A comprehensive review study

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Abstract

Radiology has experienced a growing trend of interest and exploration in artificial intelligence (AI) research. It is seen as a promising tool for diagnosis and triage, but there are concerns about its implementation. Our main goal was to understand the true impact of AI in radiology and how it can be used to enhance the radiology workflow. This comprehensive review aimed to provide an overview of AI in radiology, explore AI ethics, and examine AI clinical applications. A total of 22 relevant articles from 2018 to 2024 were selected from the Internet based on specific search criteria, including keywords such as artificial intelligence, radiology, machine learning, and deep learning. This study focused on gathering information on the benefits and role of AI in facilitating workflow in a highly efficient and effective manner in various radiological modalities and their applications in medical areas. AI may progressively alter clinical practice by assisting radiologists in achieving better performance, interpreter dependability, and patient outcomes. Additionally, AI can help modify workflows to provide more timely recommendations. This review confirms that AI still faces some obstacles in radiology. However, we firmly believe that AI can have a positive influence on radiology if used as a supporting tool rather than a substitute for human expertise. It is important to recognize the value of AI as a tool for healthcare professionals that enhances their abilities and ultimately improves patient care and patient outcomes.

Keywords: Artificial intelligence, Deep learning, Machine learning, Radiology, Workflow.

DOI: 10.53894/ijirss.v8i7.10514
Funding: This study received no specific financial support.
History: Received: 05 August 2025 / **Revised:** 10 September 2025 / **Accepted:** 15 September 2025 / **Published:** 6 October 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Acknowledgment: We extend our gratitude to our colleagues and the participants who participated in the finalization of this study.
Publisher: Innovative Research Publishing

1. Introduction

Artificial intelligence (AI) refers to computer systems capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, decision-making, and language understanding. Machine learning (ML) is a process through which a computer enhances its performance, such as by analyzing image files and integrating new data into an existing statistical model. Deep learning (DL) is a form of ML characterized by multiple layers of nodes positioned between the input and output layers, simulating layers of neurons in what is known as an artificial neural network. DL underpins many recent advancements, such as speech recognition, image classification, text understanding, and autonomous vehicles [1].

Within the context of value-based healthcare and its associated value equation, where value is determined by the ratio of outcomes to costs, AI can enhance value by either decreasing costs or increasing the health outcomes. In the medical literature and research domains, terms such as AI, ML, DL, big data, and other digital concepts are prevalent. Among all clinical disciplines, radiology has been most significantly impacted. Various perspectives exist on the use of ML and DL in radiology [2].

In radiology, we identified the primary objectives of AI, which can be achieved through various sub-objectives, as follows: streamlining workflow efficiency, reducing reading times, minimizing doses and contrast agents, enabling earlier disease detection, enhancing diagnostic precision, and providing personalized diagnostics [3].

In terms of healthcare, AI can also automate the process of patient safety screening in radiology by examining electronic health record (EHR) data to specifically identify contraindications for computed tomography (CT) and magnetic resonance imaging (MRI) scans, as mentioned by Pierre, et al. [4]. AI combined with augmented reality/virtual reality could help interventional radiologists make faster, better, more efficient, and cost-effective decisions in terms of diagnosis, planning, and treatment management by facilitating earlier disease identification and earlier treatments at an earlier time [4, 5].

Image classification, segmentation, super-resolution, and image reconstruction have all undergone breakthroughs in medical imaging. Consequently, AI can be used to accelerate MR imaging, which is possible with underdamped image reconstruction methods and super-resolution [6, 7].

AI technology has the potential to significantly enhance clinical procedures and administrative work in the healthcare sector. It has the potential to increase effectiveness, consistency, and efficiency [7, 8].

2. Methods

For this literature review on AI in radiology, we searched the Internet for review articles published between 2018 and 2024. Moreover, we narrowed our search according to our requirements, such as AI in radiology, AI ethics, and clinical applications. Finally, we selected 22 articles relevant to our study.

We performed a literature search by using the keywords “artificial intelligence”, “radiology”, “machine learning,” and “deep learning.” All published research was conducted using a centralized database (i.e., Web of Science Core Collection and Clarivate Analytics), which searches the world’s main scholarly journals and proceedings in the sciences, as well as the MEDLINE and PubMed databases.

From 2018 to 2024, all AI-related articles were selected using the following search terms: “Artificial intelligence,” “AI,” Convolutional neural networks “CNNs,” Artificial Neural Networks “ANNs,” “neural networks,” “machine learning,” “deep learning,” “computer learning,” “support vector machine,” “support vector machines,” “Bayesian network,” “Bayesian networks,” “cluster analysis,” “feature learning,” “feature extraction,” and “principal components analysis” were used to find all the required related recent and available publications. The preset database category “radiology, nuclear medicine, medical imaging” was used to identify AI research in radiology. The database was then organized by country of origin, funding agency, organization, publication type, and journal.

Most of the articles were systematic review studies; from those papers, we analyzed the benefit of AI in various radiological modalities, including MRI, US, and positron emission tomography (PET) scans, as well as the applications of these benefits in medical aspects, such as trauma and emergency medicine, maxillofacial medicine, and nuclear medicine.

We performed a literature search through the MEDLINE (PubMed) and EMBASE databases, detailed data extraction of trial characteristics, and narrative synthesis of the data.

2.1. Ethical approval and consent to participate:

The ethical approval was obtained from the Institutional Review Board (IRB) of Batterjee Medical College for Science and Technology (BMC), Res-2022-0020, Jeddah, Saudi Arabia.

3. Results

ML contains several powerful techniques with the potential to greatly increase the amount of information radiologists extract from images, and it will revolutionize radiology [9].

CNNs are a type of DL that has recently gained popularity owing to their strong performance in image recognition. Because DL performs well in image recognition tasks, its use in radiology is growing. If external performance and interpretability increase, AI may progressively alter clinical practice by assisting radiologists in achieving better performance, greater interpreter dependability, and improved patient outcomes. Additionally, AI can help modify workflows to provide more timely recommendations.

Table 1 summarizes each author and the findings of the articles, and the specialty of radiology in which they are introducing AI roles.

Table 1.
Lists the authors and their findings.

Study / Author(s)	Specialty / Modality	Key Findings
Bluemke [10]	X-ray (Fractures)	Various AI vendors have developed fracture detection models and tools for routine practice.
Yasaka and Abe [11]	X-ray (Fractures)	AI tools offer potential solutions to improve fracture detection and ultimately enhance patient care.
Rajpurkar, et al. [12]	Chest Radiography	Deep Learning (DL) models in chest radiography can detect clinically significant abnormalities.
Beregi, et al. [2]	Radiology Practice	AI is a promising adjunctive tool for diagnosis and triage, serving as a reliable support for radiologists.
Auffermann, et al. [13]	Cardiothoracic Radiology	AI can assist in interpreting cardiothoracic images and enhance patient care.
Pakdemirli [14]	X-ray (Fractures)	AI helps avoid missed opportunities for fracture intervention.
West, et al. [15]	CT	AI improves efficiency and accuracy by integrating the full spectrum of patient data into radiology practice.
Deyer and Doshi [16]	X-ray	AI integration enhances patient care and clinical management.
Hung, et al. [17]	Pediatric Radiology, Dental & Maxillofacial Radiography	AI aids in fracture detection in children, automates dental landmark localization, and assists in diagnosing osteoporosis and periodontal disease.
Johnson, et al. [5]	MRI	AI-based DL reconstruction models accelerate MR acquisitions and improve clinical quality.
Alahmari [18]	Interventional Radiology	AI rapidly identifies urgent imaging findings and supports radiologists in critical decision-making.
Zaharchuk and Davidzon [8]	Imaging Data & Image Quality	AI post-processing enhances PET/CT and PET/MRI, supporting better diagnostic decisions.
Jalal, et al. [9]	Emergency & Trauma Radiology, Ultrasound	AI improves image quality, safety, and acute abnormality detection. It also assists with data acquisition and measurements in ultrasound.
Gurgitano, et al. [6]	Neuroradiology	AI supports fast, accurate diagnosis in stroke, psychiatric disorders, and Alzheimer’s disease.
Malamateniou, et al. [19]	Medical Imaging	AI is increasingly being implemented in clinical practice and is expected to grow in use in both short- and long-term future.
Debnath [20]	X-ray	AI reduces time spent on repetitive non-interpretive tasks, letting radiologists focus on interpretation and diagnosis.
Najjar [21]	Medical Imaging	AI improves diagnostic accuracy, workflow efficiency, and supports personalized patient care.
Shiyam Sundar, et al. [22]	Clinical Radiography	DL systems enhance image interpretation, aiding in diagnosing rare diseases and incidental findings.
Pauling, et al. [23]	Medical Imaging Analysis	AI algorithms detect even minor fractures with high precision.
Shiyam Sundar, et al. [22]	PET Imaging	AI assists in tumor detection and PET image interpretation.
Strubchevska, et al. [24]	X-ray (Skeletal System & Chest)	AI enhances image quality and disease detection, boosting diagnostic accuracy and efficiency.
Flory, et al. [25]	CT	AI/ML supports clinical practice, education, and training while improving workflow and diagnostic performance.

A comparison of AI technologies in medical imaging based on the studies according to the field of application is presented in Table 1.

- X-ray: AI helps improve fracture detection ([10], Yasaka and Abe [11]; Deyer and Doshi [16]; Debnath [20] and Strubchevska, et al. [24]). AI enhances skeletal and chest image analysis [24].
- Computed Tomography (CT): AI improves diagnostic accuracy and workflow efficiency [15, 25] .
- Magnetic Resonance Imaging (MRI): AI-based deep learning models accelerate scan times and improve image quality [5].
- Pediatric and Dental Radiology: AI aids in detecting fractures in children and automating cephalometric landmark localization [17].
- Positron Emission Tomography (PET) and Molecular Imaging: AI supports tumor detection and enhances PET/MRI and PET/CT analyses [8, 22].

- Interventional Radiology: AI quickly identifies urgent cases and assists radiologists in making informed decisions [18].

3.1. According to AI Performance vs. Human Radiologists

- AI improves the accuracy of fracture and abnormality detection compared to humans, while enhancing image quality [9, 23]. It reduces repetitive tasks, allowing radiologists to focus on complex diagnoses [20].
- Efficiency and workflow Improvement: AI reduces processing time and enhances workflow by streamlining image analysis [19, 21].
- Deep learning (DL) models improve image interpretation, aiding in rare disease detection and incidental findings [22].
- Continuous AI training and high-quality datasets are necessary to maintain accuracy and reliability of the AI models.

3.2. AI in Radiology

As Zaharchuk and Davidzon [8] stated, radiologists will be crucial in categorizing training datasets and generating new information from imaging data, some of which will be inspired by the models utilized to help in imaging study protocols. Neural networks are being developed to help technicians acquire high-quality medical images. Post-processing AI can extract information from medical photos that the human eye cannot, thereby supporting diagnostic decision-making [8].

In the clinic, radiologists will continue to play critical roles in diagnosing rare diseases and detecting incidental findings, even if current DL systems excel in image interpretation [22]. Partnerships between radiologists, doctors, and data scientists, bolstered by the expanding strength of clinical informatics, are beginning to raise optimism for a time when ML can be fully integrated into medical imaging [9].

Preliminary AI diagnoses that detect acute abnormalities assist radiologists in prioritizing imaging tests. Clinical assistance is also provided. Emergency doctors and clinicians are using AI to combine a complicated array of clinical data, including imaging results, into decision-support algorithms that aim to improve patient care at the bedside. AI plays a role in improving picture quality, safety, and utility, and has the potential to positively influence emergency and trauma radiology and clinical practice, as order entry optimization is utilized to avoid needless imaging procedures [9].

Hung, et al. [17] and Pauling, et al. [23] mentioned that AI is highly valuable in pediatric radiology because it enhances the precision of identifying and diagnosing fractures in children. By analyzing medical images, AI algorithms help radiologists detect even minor fractures or abnormalities, ensuring timely clinical support in emergencies and traumatic situations [17, 23].

3.3. AI and Imaging Modalities

DL models trained on 3-D ultrasound data, ultrasound cine clips with multiple views of lesions, or spatiotemporal data could potentially improve diagnostic accuracy and detect complete lesions. This was discussed by Jalal, et al. [9], who mentioned that AI provides operators with AI guidance during data acquisition and measurement, which would also make ultrasound more intelligent and less operator-dependent [9]. Figure 1 explains more about using AI in ultrasonography [26].

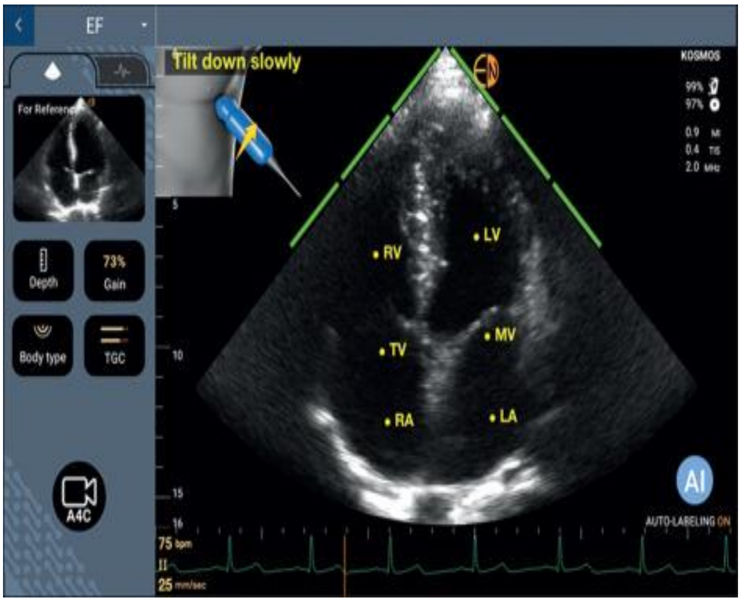

Figure 1.
AI-assisted ultrasound guidance interface demonstrating optimal probe positioning for a standard apical four-chamber (A4C) view. Cardiac chambers (RA, RV, LA, LV) and atrioventricular valves (TV, MV) are automatically labelled. Real-time guidance prompts (e.g., "Tilt down slowly") and probe orientation indicators support accurate image acquisition.
Source: Muse and Topol [26].

Accelerating MRI acquisitions is an active area of research motivated by the long acquisition times of current clinical protocols. AI-based methods for accelerating MR acquisitions include undersampled image reconstruction methods and super-resolution techniques. Undersampled image reconstruction methods can be applied in both image and k-spaces and have shown promising results for musculoskeletal MRI applications. Promising directions for future development include extending DL reconstruction models to use 3D CNNs and joint multi-contrast training, thoroughly evaluating the diagnostic accuracy of AI-accelerated images to ensure that clinical quality is not compromised, and expanding available benchmark datasets [5].

AI has several possible applications in dental and maxillofacial radiography, such as the automated localization of cephalometric landmarks, osteoporosis diagnosis, classification/segmentation of maxillofacial cyst tumors, and periodontitis/periapical disease detection [17, 23].

Figure 2,3 represents dental lesions and the role of AI, respectively [27, 28].

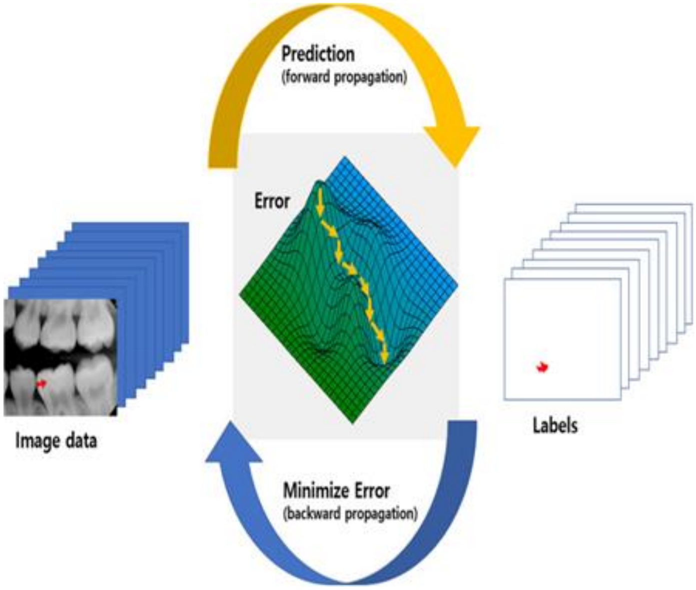

Figure 2.
Schematic representation of the deep learning training process for caries segmentation in periapical radiographs. The model performs prediction via forward propagation, compares outputs with labeled ground truth, and minimizes error through backward propagation to optimize performance.
Source: Heo, et al. [27].

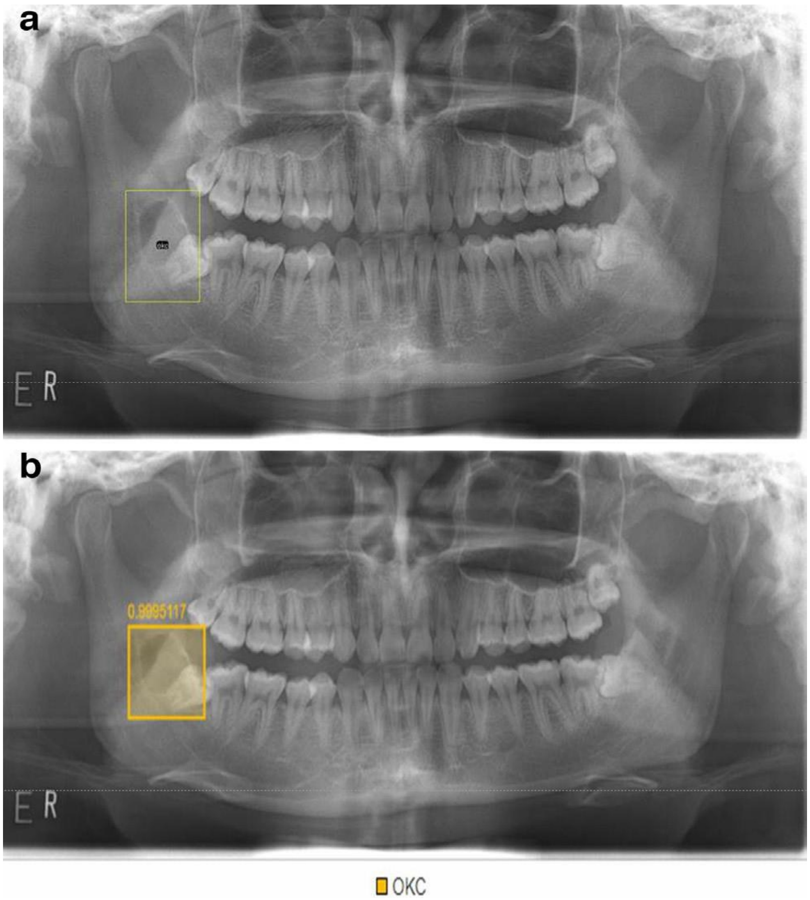

Figure 3.
Automatic detection of odontogenic keratocyst (OKC) in the right posterior mandible on panoramic radiographs. (a) Original radiograph with lesion location outlined. (b) Deep-learning model output highlighting the lesion with a confidence score.
Source: KUMAR [28].

Alahmari [18]& Auffermann, et al. [13] conclude that DL breakthroughs in cardiothoracic radiology will redefine the discipline and lead to changes in how we interpret cardiothoracic images and care for our patients. We may witness huge changes in the way we care for our patients because of the improved accuracy of emerging AI algorithms [13, 18].

Some AI radiology inventions on the market can perform a variety of tasks, such as identifying hemorrhages, detecting coronary artery disease without contrast media, and detecting tuberculosis, cardiomegaly, fibrosis, fractures, pneumonia, and other diseases. All imaging studies will be examined by a robotic radiologist before a human radiologist in the next ten years. Furthermore, AI can quickly identify urgent medical imaging situations and present them to human radiologists, resulting in a favorable impact on healthcare by highlighting urgent areas [18].

AI improves the image quality, safety, and utility of PET/CT and PET/MRI for molecular imaging. Many challenges mentioned by Zaharchuk and Davidzon [8], however, remain, such as acquiring and curating large medical datasets in representative populations and with adequate representation of major imaging vendors. One need is the collaboration of AI scientists, molecular imaging researchers, and physicians to ensure that the use cases explored and the algorithms developed are those that will push the field forward to explore new and exciting innovations and ultimately add value to improving patient care [8]. Figure 4. shows how AI assists in tumor detection in PET imaging [29].

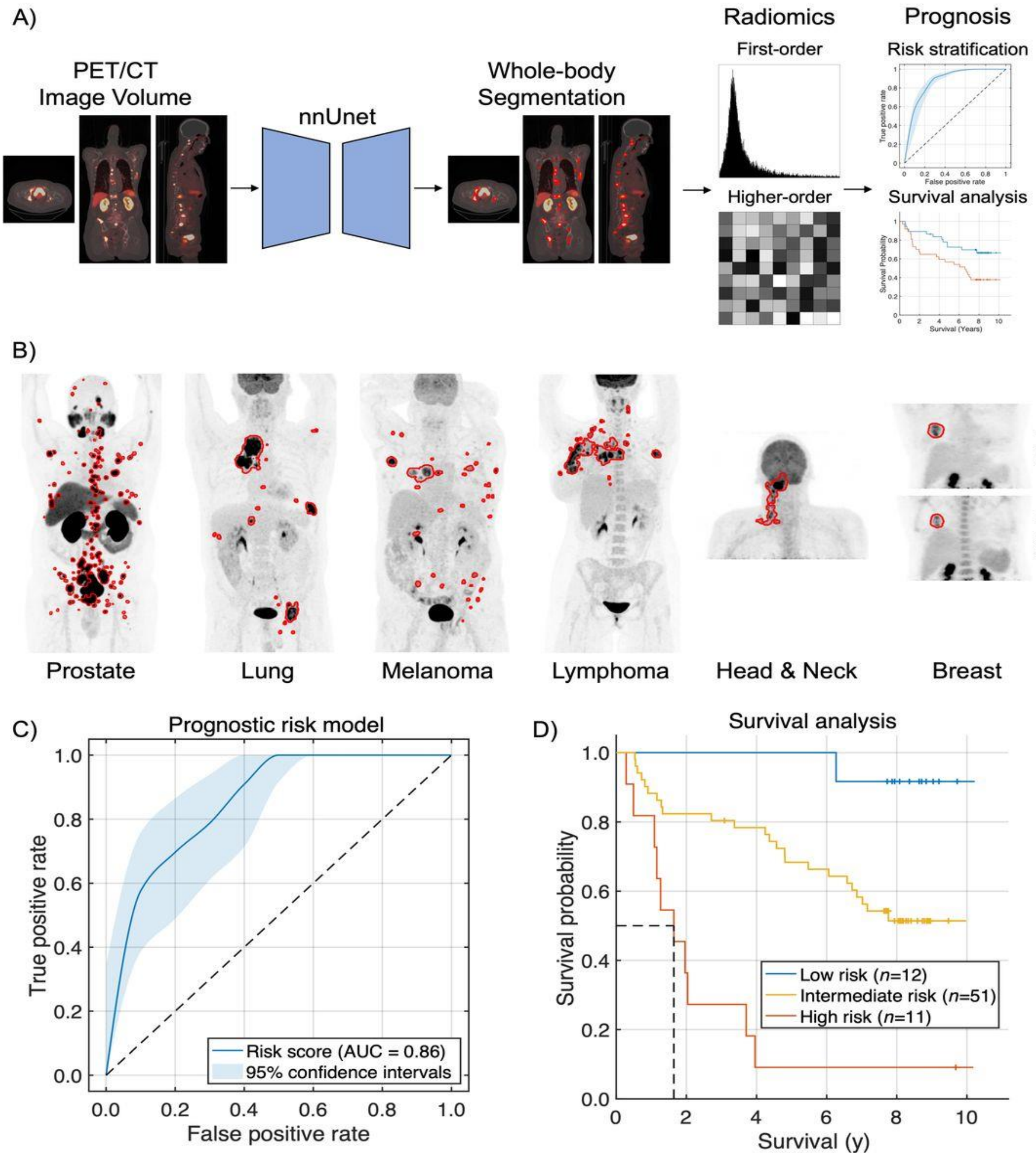

Figure 4.
Illustrative examples of predicted tumor segmentations by the deep transfer learning approach across six cancer types, including pre- and post-therapy scans for breast cancer.
Source: Leung, et al. [29].

Neuroradiology, body and chest radiology, and nuclear medicine were the three most productive subspecialties. The neuroradiology subspecialty produced the majority of AI papers. This is not surprising, considering that neuroradiology is a distinct specialization of acuity for stroke evaluation, necessitating a quick and accurate diagnosis, which is ideal for AI. Other neurological disease processes, such as traumatic brain injury and demyelinating diseases (multiple sclerosis), are well matched to AI applications [6].

In addition to tumor assessment, AI applications are also used for other neurological diseases, such as psychiatric disorders and dementia (Alzheimer's disease). Further studies are needed to further comprehend the intricacies of AI radiology research in neuroradiology and other radiology subspecialties [13, 18, 22].

Missed fractures have significant implications for both patients and healthcare providers, especially in young children, where they may indicate missed opportunities for intervention and referral to social services. To mitigate such errors, the integration of assistance from AI could be beneficial. Various AI vendors have developed fracture detection models and tools for routine practice, such as Gleamer, which focuses on acute and healing fractures in the wrist, foot, knee, and humerus. AZmed specializes in detecting traumatic injuries in the dental, facial, skull, and spine regions, and Milvue detects fractures, dislocations, and effusions in the abdomen, dental area, and axial skeleton. These AI tools offer potential solutions for improving fracture detection and ultimately enhancing patient care [10, 11, 14].

DL models in chest radiography can detect clinically significant abnormalities, such as edema, fibrosis, masses, pneumonia, and pneumothorax, with a performance level comparable to that of experienced radiologists [12, 15].

3.4. AI Advantages and Disadvantages

In radiology, AI can be used to evaluate all patients automatically, suggest differential diagnoses, process data, and review all previous radiology scans for patient-like conditions, allowing AI to arrive at an accurate diagnosis in a short amount of time and at a low cost, as the robotic radiologist can work without fatigue and the need for a break or salary [18].

One of the benefits listed by West, et al. [15] is that AI will improve our practice by helping us better integrate the whole spectrum of data accessible for each patient, allowing us to provide accurate and individualized treatment tailored to each patient. In geographic areas where radiology resources are scarce (e.g., poor nations), AI will be useful for picture triaging to optimally choose patients for referral to specialist treatment centers [15].

AI increases the efficiency and accuracy of interpreting radiologic studies compared to human radiologists, and it gathers additional information from radiologic tests that radiologists cannot see. Many AI algorithms can demonstrate outstanding diagnostic accuracy on one dataset but perform significantly worse on another. Unexpected information in an image can occasionally mislead image recognition [15].

The advent of DL has propelled diagnostic radiology by enhancing image analysis and interpretation. The introduction of transformer architecture, followed by the development of Large Language Models (LLMs), has further revolutionized this domain. LLMs have the potential to automate and refine radiology workflows, extending from report generation to assistance in diagnostics and patient care [30, 31].

LLM is currently evolving rapidly, and multimodal technology appears to be one of the most notable and relevant technologies in the field of radiology. Similar to LLM, this technology is based on a transformer architecture but can also handle image data in a unified manner [30].

The integration of multimodal technology into LLM or AI in medical imaging may bring a new dimension to radiology. According to previous research, the integration of multimodal technology has the potential to revolutionize the precision of image diagnosis in diagnostic radiology. Moreover, its implementation can substantially reduce the time required for image analysis. However, given that, as with research work, LLMs are not responsible and may produce reports that seem authoritative with a completely different meaning through hallucinations and given that multimodal technology is prepared for use by people with no knowledge of the radiology field, multimodal technology may prepare people with no knowledge of radiology to use it. Legal developments and guidelines may be needed for the application of this technology in radiology [30].

The disadvantages of AI arise in complex scenarios. Because AI depends on the database on which it is based, the AI system will only be able to detect the diseases it has been taught to recognize and detect based on the database on which it was trained. AI cannot comprehend the grey area in radiology and medicine; no one, for example, can say if a certain alteration is pathological or normal, such as aging, artifacts, and anatomical variance. In addition, patients are often hesitant to trust a machine's diagnosis, fearing that it will make mistakes [18].

4. Discussion

4.1. Challenges and Limitations of AI in Medical Imaging

We are currently witnessing a major paradigm shift in the design principles of many clinically used computer-based tools. There is great debate about the speed with which newer deep learning methods will be implemented in clinical radiology practice, as Lee, et al. [32] stated, with speculations for the time needed to fully automate clinical tasks ranging from a few years to decades [32]. The development of deep-learning-based automated solutions will begin by addressing the most common clinical problems for which sufficient data are available. These problems could involve cases where human expertise is in high demand or data are too complex for human readers; examples include the reading of lung screening CTs, mammograms, and images from virtual colonoscopy. The second wave of efforts is likely to address more complex problems, such as multiparametric MRI. A common trait among current AI tools is their inability to address more than one task, as is the case with any narrow intelligence. A comprehensive AI system capable of detecting multiple abnormalities in the human body has not yet been developed [19, 24].

Despite the promising advantages of AI in radiology, several limitations have hindered its full integration into clinical practice. One significant concern is the risk of algorithmic bias, where AI systems may perpetuate existing disparities in healthcare owing to training on non-representative datasets [20, 25, 33].

Additionally, there are concerns regarding the lack of transparency in AI decision-making processes, which makes it challenging for radiologists to understand the rationale behind certain outputs of AI systems. The expansion of AI in healthcare, particularly in diagnostic radiology, has provided unprecedented opportunities to enhance the quality and efficiency of patient care. Despite this, rapid growth comes with a myriad of challenges, including the necessity for adequate data quality and volume, the "black box" dilemma, integration into clinical practice, and ethical considerations. This section dissects these issues and proposes potential resolutions that could facilitate the assimilation and responsible usage of AI in radiology while addressing various technical, infrastructural, regulatory, and human Factors [21] as in Figure 5

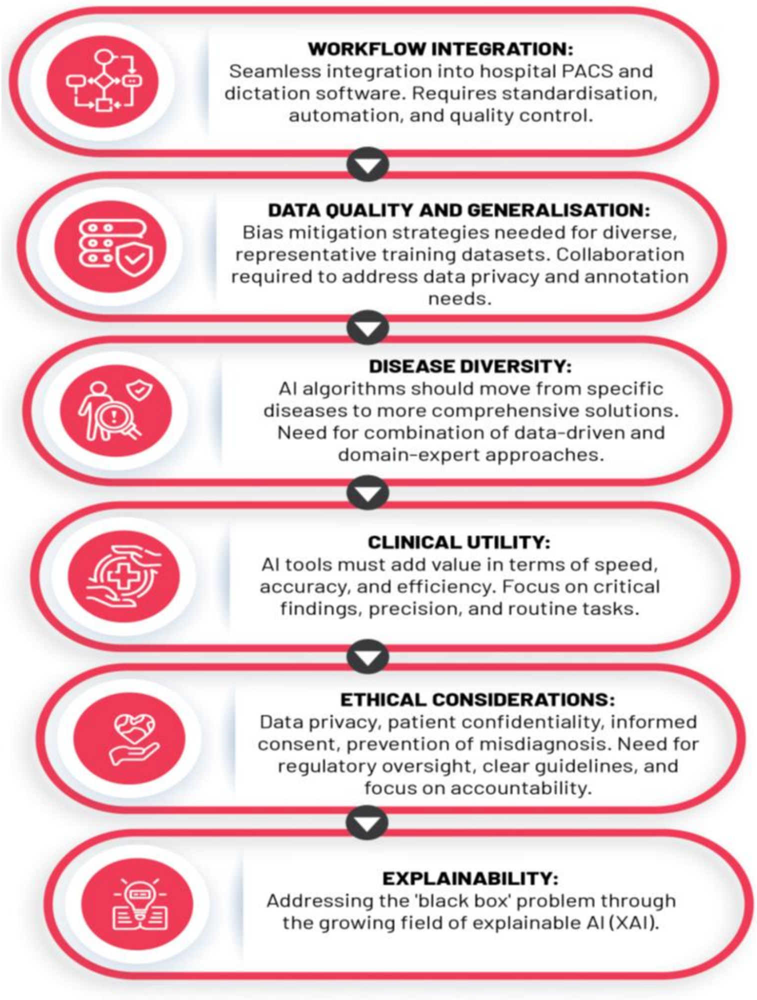

Figure 5.
Challenges associated with the integration of artificial intelligence into clinical practice, including workflow integration, data quality, disease diversity, clinical utility, ethical considerations, and explainability.
Source: Najjar [21]

4.2. AI in the future:

Because AI technologies may create medical errors, especially in patients with complex diseases, they should not be used without radiologist supervision. Furthermore, the radiologist's job is not limited to picture interpretation. It is a lot more complicated because responsibilities include everything from validating the imaging study request to disclosing the results by doing the required imaging study [15]. While AI is still awaiting approval from health regulators and governmental bodies, it appears to be a promising adjunctive tool for diagnosis and triage and a reliable, hard-working friend rather than a foe to radiology, despite some reservations about its implementation in radiology practice. It should be included in radiology training curricula shortly [2].

In the long run, AI will be trained in the future to tackle any complex situation, and radiologists with less experience may be replaced. According to some predictions, professional radiologists will only be able to analyze complex cases and AI reports by 2030. In the case of interventional radiologists, AI has not yet been proven to be a threat to angiographers and interventionists. Alahmari [18] said that radiographers can simply be replaced by AI, as companies have already developed new methods for automatically positioning patients, picking slices, and altering scans. Patients prefer to work with humans rather than robots; therefore, radiographers will have a greater chance of keeping their careers than radiologists, who are already directly involved in the huge developments brought about by Alahmari [18]. Their dedication will be required in the future to build and undertake clinical validation of AI system training databases. Their collaboration will be required to integrate AI into the radiology process, ensuring that effective tools for patient care and management are provided as soon as possible [16].

5. Conclusion

AI, which uses DL and ML techniques, improves the efficiency and accuracy of interpreting radiologic studies in comparison to human radiologists. It also provides additional information from radiologic studies that radiologists are not aware of. Radiologists will be crucial in categorizing training datasets and extracting new knowledge from image data.

There are numerous obstacles to AI applications in radiology, including incorrect picture interpretation, since image recognition might be misled by unexpected information in an image; also, most radiological databases are not adequately labeled to be used for AI. AI plays a role in evaluating simple medical cases and suggesting differential diagnoses. It processes the data and reviews all previous radiology scans for patient-like conditions to reach a diagnosis in a short time and ultimately enhance patient care.

AI is rapidly advancing in medical imaging, significantly improving diagnostic accuracy and efficiency. The most impacted fields include X-ray, CT, and MRI, where AI aids in early disease detection and better patient care. However, human oversight remains essential to ensure correct interpretations and maximize AI's potential. AI should be integrated into traditional diagnostic workflows without replacing human expertise entirely. Continuous AI training and high-quality datasets are necessary to maintain accuracy and reliability.

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