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AI in diagnostic imaging: Revolutionising accuracy and efficiency

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A R T I C L E I N F O

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A B S T R A C T

Introduction: This review evaluates the role of Artificial Intelligence (AI) in transforming diagnostic imaging in healthcare. AI has the potential to enhance accuracy and efficiency of interpreting medical images like X-rays, MRIs, and CT scans.

Methods: A comprehensive literature search across databases like PubMed, Embase, and Google Scholar was conducted, focusing on articles published in peer-reviewed journals in English language since 2019. Inclusion criteria targeted studies on AI's application in diagnostic imaging, while exclusion criteria filtered out irrelevant or empirically unsupported studies.

Results and discussion: Through 30 included studies, the review identifies four AI domains and eight functions in diagnostic imaging: 1) In the area of Image Analysis and Interpretation, AI capabilities enhanced image analysis, spotting minor discrepancies and anomalies, and by reducing human error, maintaining accuracy and mitigating the impact of fatigue or oversight, 2) The Operational Efficiency is enhanced by AI through efficiency and speed, which accelerates the diagnostic process, and cost-effectiveness, reducing healthcare costs by improving efficiency and accuracy, 3) Predictive and Personalised Healthcare benefit from AI through predictive analytics, leveraging historical data for early diagnosis, and personalised medicine, which employs patient-specific data for tailored diagnostic approaches, 4) Lastly, in Clinical Decision Support, AI assists in complex procedures by providing precise imaging support and integrates with other technologies like electronic health records for enriched health insights, showcasing ai's transformative potential in diagnostic imaging. The review also discusses challenges in AI integration, such as ethical concerns, data privacy, and the need for technology investments and training.

Conclusion: AI is revolutionising diagnostic imaging by improving accuracy, efficiency, and personalised healthcare delivery. Recommendations include continued investment in AI, establishment of ethical guidelines, training for healthcare professionals, and ensuring patient-centred AI development. The review calls for collaborative efforts to integrate AI in clinical practice effectively and address healthcare disparities.

Introduction

Artificial Intelligence (AI) is significantly transforming the landscape of diagnostic imaging in healthcare. This technology, which integrates sophisticated algorithms and machine learning, represents a considerable advancement in the interpretation and utilization of medical images such as X-rays, MRIs, and CT scans. AI's role in diagnostic imaging is not merely about automating processes; it fundamentally changes the approach to disease diagnosis, making it more precise and efficient [1]. One of the most notable benefits of AI in this field is its ability to accelerate the analysis of medical images. Traditional methods of image interpretation can be time-consuming and subject to human error. AI, however, can process and analyse images at a much faster rate, significantly reducing the time it takes to diagnose a patient. This speed is particularly crucial in emergency situations where every second counts [2,3]. Moreover, AI enhances the accuracy of diagnoses. By learning from vast datasets of medical images, AI algorithms can identify patterns and anomalies that might be overlooked by the human eye. This increased accuracy is vital in reducing misdiagnoses and ensuring patients receive the correct treatment promptly [3].

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Another significant advantage of AI is its predictive capability. AI can analyse historical data and identify trends or risk factors, enabling early detection of diseases, which is often key in improving patient outcomes, especially in conditions like cancer where early intervention can alter the prognosis [4]. AI is also instrumental in the shift towards personalised medicine. By analysing a patient's specific characteristics and medical history, AI can provide tailored insights, leading to more personalised and effective treatment plans. This individualised approach represents a major advancement in healthcare delivery, moving away from a one-size-fits-all model [5]. However, the integration of AI in diagnostic imaging is not without challenges. Concerns around data privacy, potential biases in AI algorithms, and the need for significant investment in technology and training are some of the hurdles that need to be addressed. Additionally, there's a need for clear guidelines and ethical standards to manage the use of AI in healthcare effectively [6].

This scoping review seeks to extensively examine AI's role in improving diagnostic imaging's accuracy and efficiency. It focuses on identifying key areas where AI impacts diagnostic imaging, such as image analysis, operational efficiency, and clinical decision support. The review's objectives include assessing AI's effectiveness in enhancing image accuracy and reducing human errors, using recent experimental studies. It aims to evaluate AI's current strengths and weaknesses in diagnostic imaging. This analysis is crucial for assessing AI's readiness for broader clinical application, identifying research gaps, and guiding future advancements.

Methods

The methodology approach was structured around four critical steps to ensure a detailed and rigorous evaluation of the primary literature. Initially, an exhaustive literature search was conducted, October and November 2023, across several databases, including PubMed, Embase, and Google Scholar, targeting articles published in English from 2019 onwards. This search utilized a combination of keywords and Medical Subject Headings (MeSH) terms such as "Artificial Intelligence [MeSH]," "Diagnostic Imaging [MeSH]," "Machine Learning [MeSH]," "Deep Learning [MeSH]," "X-Rays [MeSH]," "Magnetic Resonance Imaging [MeSH]," and "Tomography, X-Ray Computed [MeSH]" to pinpoint peer-reviewed articles and primary experimental studies exploring AI's role in diagnostic imaging. Cochrane and Scopus databases yielded very limited results and did not add any new studies to the found ones. Table 1 shows the detailed search strategy.

To refine the search further, inclusion and exclusion criteria were accurately developed and applied. Studies were selected for inclusion if they explicitly explored the integration of AI in enhancing diagnostic imaging facets such as image analysis, operational efficiency, and clinical decision support systems. Conversely, articles were excluded if they did not focus directly on diagnostic imaging applications, lacked empirical evidence, or had unclear methodologies.

Table 1
Search strategy terms and definitions.

Search terms	Definition/inclusion criteria
Artificial Intelligence	Includes "AI", machine learning algorithms, neural networks, deep learning.
Diagnostic imaging	Refers to techniques and processes used to create images of the human body (or parts thereof) for clinical purposes, including X-ray, MRI, CT scans.
Machine learning	Subfield of AI focused on algorithms that learn from data.
Deep learning	A subset of machine learning involving neural networks with three or more layers.
X-ray	Electromagnetic wave-based imaging used for diagnostic purposes.
MRI	Magnetic Resonance Imaging, a type of imaging using magnetic fields and radio waves.
CT-scan	Computed Tomography Scan, a diagnostic imaging procedure that uses combined series of X-ray measurements taken from different angles to produce cross-sectional images.

Following the selection process, data extraction and synthesis were performed. This involved extracting pertinent information from the qualified studies regarding AI's principal domains, pivotal findings, specific AI applications in diagnostic imaging, encountered limitations, and forward-looking recommendations. This gathered data was synthesized to delineate the main areas where AI contributes to diagnostic imaging, highlighting prevalent trends, existing challenges, and prospective avenues for further exploration.

The final step encompassed a comprehensive analysis of the synthesized information, aiming to elucidate AI's role in augmenting diagnostic imaging. This analysis focused on the achieved outcomes regarding precision and efficiency and contemplated future application prospects. Additionally, the analysis addressed the hurdles associated with AI deployment in diagnostic imaging, such as ethical dilemmas, data privacy issues, and the integration challenges within current healthcare infrastructures, thereby providing a holistic overview of AI's impact and potential in diagnostic imaging.

Results: AI domains in diagnostic imaging

Searching PubMed, Embase, and Google Scholar, 312 papers were initially identified. After removing duplicates, 271 unique papers were identified. Applying the inclusion and exclusion criteria, 141 papers were excluded after title screening. Of the remaining 130 papers, only 75 studies were assessed for full-text eligibility after abstract screening. Finally, 30 studies, discussing the roles of AI in improving academic writing and research, were included in this review. Fig. 1 shows the study selection and inclusion processes.

Through careful examination and meticulous qualitative analysis, this scoping review identified four domains and eight functions where AI have the potential to enhance the accuracy of diagnostic imaging and support its efficiency, shown in Fig. 2. The first domain, Image Analysis and Interpretation, AI's effectiveness in Enhanced Image Analysis is particularly noteworthy. It excels at detecting complex patterns in medical images, identifying anomalies that are often imperceptible to the human eye, thus significantly enhancing the precision of diagnoses in complex cases like cancer or neurological disorders [7–12].

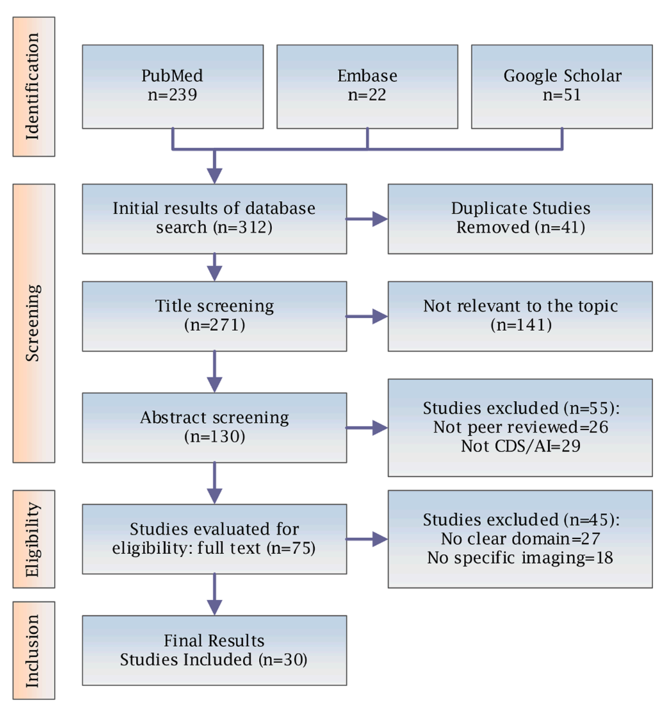

Fig. 1. PRISMA flowchart of study selection and inclusion process.

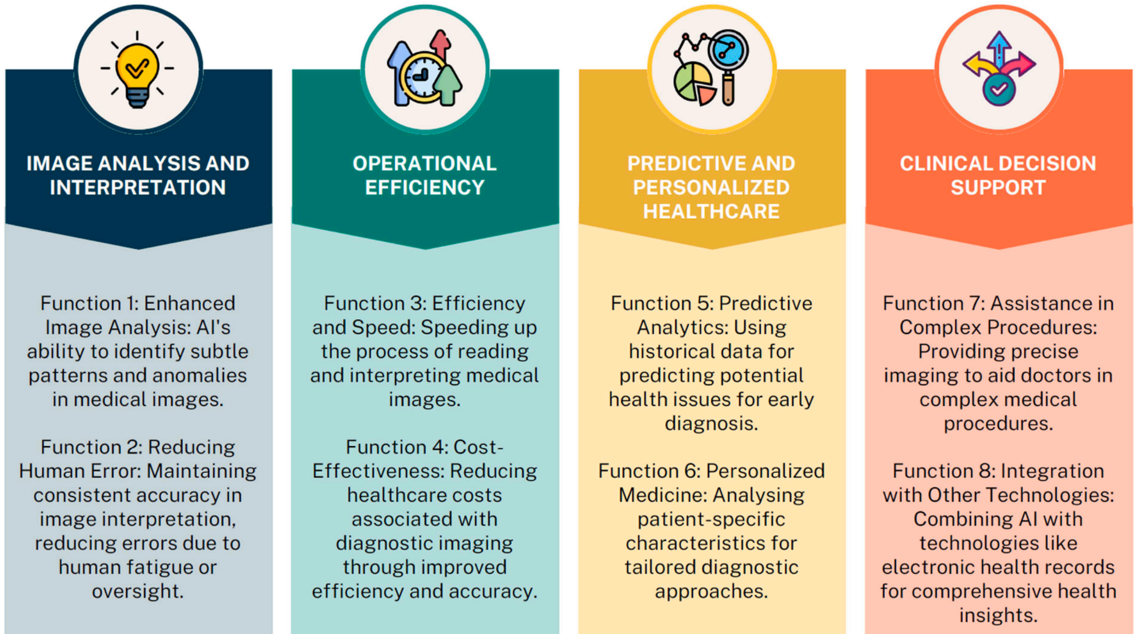

Fig. 2. The AI four domains and eight functions in diagnostic imaging.

Complementing this, AI plays a vital role in Reducing Human Error. By maintaining consistent accuracy, AI effectively counters the challenges posed by human fatigue and oversight, ensuring reliable interpretations regardless of external factors [13–17]. Moving to the second domain, Operational Efficiency, AI contributes immensely in terms of Efficiency and Speed, dramatically speeding up the process of interpreting medical images. This acceleration is critical, not just for convenience but for potentially life-saving scenarios where rapid treatment decisions are needed [10,18,19]. Additionally, AI's role in Cost-Effectiveness cannot be understated. By improving both efficiency and accuracy, AI reduces the need for repeat scans and minimizes misdiagnosis risks, thereby reducing overall healthcare expenditure [20].

In the third domain, Predictive and Personalised Healthcare, AI's capability in Predictive Analytics uses historical data to forecast potential health issues, facilitating early diagnosis and intervention. This predictive analysis is pivotal in identifying risks before they develop into serious conditions, enabling proactive healthcare strategies [21–30]. Moreover, AI's application in Personalised Medicine allows for tailoring diagnostic approaches to individual patient characteristics, leading to more accurate diagnoses and customised treatment plans, enhancing the personalization of healthcare [11]. Lastly, in the fourth domain, Clinical Decision Support, AI provides indispensable Assistance in Complex Procedures through precise imaging. This support is crucial in enhancing the surgeon's ability to navigate complex operations, thereby increasing the chances of successful outcomes [15-17,31-36]. Furthermore, AI's Integration with Other Technologies, like electronic health records, offers comprehensive health insights. This integration not only streamlines patient care but also enriches clinical decision-making with a holistic view of patient health history and current conditions [14]. Tables 2 and 3 show the characteristics and extracted information of the 30 included studies, while Table 4 shows the mapping the studies to the domains and functions. Fig. 3 shows the AI potential contribution to diagnostic imaging, based on the included studies.

Based on quantitative analysis, AI excels in five of the identified eight functions. The role of AI in predictive analytics of diagnostic imaging was discussed in ten studies (33 %), its ability to assist in complex procedures was discussed in nine studies, its ability to speed up processes and improve efficiency was discussed in seven studies, its role in enhancing image analysis accuracy was discussed in six studies, and its role in reducing human errors was discussed in five studies. On the other hand, AI role in cost-effectiveness, integration with technology, and personalised medicine was less discussed, each by 3 % of studies.

Discussion and detailed analysis

Domain one: image analysis and interpretation

In the area of medical imaging, AI's enhanced image analysis capabilities and revolutionised the way fine patterns and anomalies are identified. AI algorithms, particularly those based on deep learning models like convolutional neural networks (CNNs), have demonstrated remarkable efficiency in detecting complex details in medical images that might be challenging for human eyes to detect [1]. This advanced capability is evident in various studies, such as the identification of positive circumferential resection margins in rectal cancer through high-resolution MRI using Faster R-CNN, a type of CNN [17,36]. The CNNs were also successful in enhancing detecting lung nodules in complex lung disease, from chest CT scans, compared to experienced radiologists [10]. CNNs and segmentation AI algorithm were effective in analysing multimodal ultrasound images to diagnose small liver cancer, showing high accuracy and precision [12]. Similarly, the EyeArt, an AI automated algorithm, successfully enhanced the detection of more-than-mild and vision-threatening diabetic retinopathy without the need for dilation, indicating AI's ability to accurately detect fine retinal changes using retinal imaging [7]. AI algorithms also could enhance the image analysis of age-related macular degeneration and predict future disease progression [9]. Likewise, the Gastrointestinal Artificial Intelligence Diagnostic System (GRAIDS) achieved high diagnostic accuracy and sensitivity, compared to expert endoscopists, in identifying cancerous lesions in endoscopy images [8]. Moreover, AI systems improved diagnostic accuracy, particularly in distinguishing gastrointestinal stromal tumours from gastrointestinal leiomyomas, using endoscopic ultrasonography [11].

Furthermore, AI's role in reducing human error in image interpretation is of great importance. The consistency and accuracy maintained by AI systems address issues of human fatigue and oversight. In studies where AI was applied to evaluate cervical spondylotic myelopathy using lateral cervical spine radiograph [35], or in the differentiation of breast lesions on dynamic contrast-enhanced MRI [30], AI demonstrated its potential in providing reliable and error-reduced interpretations. In

Table 2
Objectives, design, settings, and imaging techniques of the 30 included studies.

SN	Study	Title	Objective	Study design	Population & setting	Imaging technique
1	Ipp E et al., 2021	Pivotal evaluation of an Artificial Intelligence system for autonomous detection of referrable and vision-threatening diabetic retinopathy	To evaluate the safety and accuracy of an AI system in detecting both more-than-mild diabetic retinopathy (mtmDR) and vision-threatening diabetic retinopathy (vtDR)	Prospective multicenter cross-sectional diagnostic study	942 individuals with diabetes at 15 primary and eye care facilities	2-field undilated fundus photography
2	Luo H et al., 2019	Real-time Artificial Intelligence for detection of upper gastrointestinal cancer by endoscopy	To develop and validate the Gastrointestinal Artificial Intelligence Diagnostic System (GRAIDS) for the diagnosis of upper gastrointestinal cancers through analysis of imaging data from clinical endoscopies	Multicentre, case-control, diagnostic study	84,424 individuals undergoing endoscopy in six hospitals	Endoscopy imaging
3	Waldstein SM et al., 2020	Characterization of Drusen and hyperreflective foci as biomarkers for disease progression in age-related macular degeneration using artificial intelligence in optical coherence tomography	To characterize the distribution and time course of morphologic patterns in AMD and quantify changes distinctive for progression to macular neovascularization (MNV) and macular atrophy (MA)	Cohort study	518 patients with early or intermediate AMD in the HARBOR trial	Optical coherence tomography (OCT)
4	Abadia AF et al., 2022	Diagnostic accuracy and performance of artificial intelligence in detecting lung nodules in patients with complex lung disease: a noninferiority study	To investigate the performance of AI convolutional neural networks in detecting lung nodules on chest CT in patients with complex lung disease, and demonstrate its noninferiority compared against an experienced radiologist	Noninferiority study	103 complex lung disease cases and 40 control cases without reported nodules	Chest computed tomography (CT)
5	Yang X et al., 2022	An Artificial Intelligence system for distinguishing between gastrointestinal stromal tumors and leiomyomas using endoscopic ultrasonography	Develop an AI system to differentiate GISTs from GILs using EUS	Multicentre prospective diagnostic study	Participants from four centers with histologically confirmed GISTs or GILs	Endoscopic ultrasonography (EUS)
6	Jonas R et al., 2021	Relationship of Age, Atherosclerosis and Angiographic Stenosis using Artificial Intelligence	Evaluate the relationship of coronary stenosis, atherosclerotic plaque characteristics, and age using AI-QCT	Post-hoc analysis of a clinical trial	303 subjects referred for invasive coronary angiography	Coronary computed tomographic angiography (CCTA)
7	Zhang Y et al., 2022	Multimodal imaging under artificial intelligence algorithm for the diagnosis of liver cancer and its relationship with expressions of EZH2 and p57	Explore diagnostic efficacy of multimodal ultrasound images using M-RCNN for small liver cancer and analyze expression of EZH2 and p57 genes	Comparative study	100 patients suspected of small liver cancer	Multimodal ultrasound imaging
8	Schwendicke F et al., 2022	Cost-effectiveness of AI for Caries Detection: Randomised Trial	Assess cost-effectiveness of AI-supported detection of proximal caries	Randomised controlled trial	23 dentists evaluating 20 bitewings	Bitewing radiographs
9	Fan X et al., 2022	Artificial Intelligence-based CT imaging on diagnosis of patients with lumbar disc herniation by scalpel treatment	Explore application effect of CT imaging based on AI algorithm in treatment of LDH with scalpel	Comparative study	78 patients with lumbar disc herniation	Computed tomography (CT) imaging
10	Upton R et al., 2022	Automated echocardiographic detection of severe coronary artery disease using Artificial Intelligence	Establish whether AI can automate stress echocardiography analysis and support clinician interpretation	Multicenter, multivendor study	Large, UK-based multicenter study	Stress echocardiography
11	Hwang EJ et al., 2023	Conventional versus artificial intelligence-assisted interpretation of chest radiographs in patients with acute respiratory symptoms in emergency department: a pragmatic randomised clinical trial	Compare accuracy of CR interpretation assisted by AI-CAD to conventional interpretation in patients with acute respiratory symptoms in ED	Randomised controlled trial	Patients with acute respiratory symptoms at tertiary referral institution's ED	Chest radiographs (CR)
12	Menzies SW et al., 2023	Comparison of humans versus mobile phone-powered Artificial Intelligence for the diagnosis and management of pigmented skin cancer in secondary care: a multicentre, prospective, diagnostic, clinical trial	Test whether AI algorithms and clinicians are equivalent in diagnosing and managing pigmented skin lesions	Multicentre, prospective, diagnostic, clinical trial	Patients from two tertiary referral centres in Australia and Austria	Skin lesion imaging
13	Du Q et al., 2022	Evaluation of functional magnetic resonance imaging under artificial intelligence algorithm on plan-do-check-action home nursing for patients with diabetic nephropathy	Evaluate effect of fMRI under FCM on PDCA home nursing for patients with DN	Comparative study	64 patients with diabetic nephropathy	Functional MRI (fMRI)
14	Kundisch A et al., 2021	Deep learning algorithm in detecting intracranial hemorrhages on emergency computed tomographies	Determine number of additional ICHs detected by AI and evaluate reasons for erroneous results	Retrospective multi-center cohort study	4946 head CT scans	Head CT scans
15	Park A et al., 2019	Deep learning-assisted diagnosis of cerebral aneurysms using the HeadXNet model	Develop a neural network model for aneurysm segmentation on head CTA imaging	Diagnostic study	818 head CTA examinations	Head CT angiography (CTA)

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Table 2 (*continued*)

SN	Study	Title	Objective	Study design	Population & setting	Imaging technique
16	Qi C et al., 2022	An Artificial Intelligence-driven image quality assessment system for whole-body [(18)F]FDG PET/CT	Develop AI-driven real-time and accurate image quality assessment system for whole-body [18F]FDG PET/CT	Developmental study	173 patients with whole-body [18F] FDG PET/CT imaging	PET/CT imaging
17	Lipkin I et al., 2022	Coronary CTA with AI-QCT interpretation: comparison with myocardial perfusion imaging for detection of obstructive stenosis using invasive angiography as reference standard	Compare diagnostic performance of MPI and coronary CTA with AI-QCT interpretation for detecting obstructive CAD	Comparative study	301 patients with stable myocardial ischemia symptoms	Coronary CTA
18	Nam JG et al., 2023	AI improves nodule detection on chest radiographs in a health screening population: a randomised controlled trial	Investigate if commercial AI-based CAD software improves detection rate of actionable lung nodules on chest radiographs	Randomised controlled trial	10,476 participants undergoing chest radiography	Chest radiographs
19	Backhaus SJ et al., 2022	Artificial Intelligence fully automated myocardial strain quantification for risk stratification following acute myocardial infarction	Evaluate automated myocardial strain quantification for risk stratification post-AMI	Prospective study	1095 AMI patients	Cardiovascular magnetic resonance (CMR)
20	Sun L et al., 2023	Exploration of the influence of early rehabilitation training on circulating endothelial progenitor cell mobilization in patients with acute ischemic stroke	Investigate the effect of rehabilitation on EPCs in AIS patients using AI algorithms in MRI imaging	Prospective study	98 AIS patients	Magnetic resonance imaging (MRI)
21	Kahn A et al., 2022	Artificial Intelligence-enhanced volumetric laser endomicroscopy improves dysplasia detection in barrett's esophagus	Assess the impact of AI algorithm IRIS on dysplasia detection in Barrett's Esophagus	Randomised cross-over study	133 patients with Barrett's Esophagus	Volumetric laser endomicroscopy (VLE)
22	Martinez-Gutierrez JC et al., 2023	Automated large vessel occlusion detection software and thrombectomy treatment times	Determine if automated CT angiogram interpretation improves in-hospital EVT workflows	Cluster randomised stepped-wedge trial	243 patients with LVO stroke	Computed tomography (CT) angiogram
23	Yin HL et al., 2023	Combined diagnosis of multiparametric MRI-based deep learning models facilitates differentiating triple-negative breast cancer from fibroadenoma	Differentiate TNBC from fibroadenoma using deep learning models based on multiparametric MRI	Retrospective study	Patients with BI-RADS 4 lesions	Multiparametric MRI
24	Lee GW et al., 2022	Deep learning algorithm to evaluate cervical spondylotic myelopathy using lateral cervical spine radiograph	Develop a CNN to detect cervical spondylotic myelopathy (CSM) using lateral cervical spine radiographs	Retrospective study	207 patients (96 CSM, 111 non-CSM)	Lateral cervical spine radiograph
25	Reza M et al., 2021	Automated bone scan index as an imaging biomarker to predict overall survival in the Zometa European Study/SPCG11	Investigate aBSI as an imaging biomarker for quantifying skeletal metastases and its predictive value for overall survival in prostate cancer	Retrospective analysis in a clinical trial	176 prostate cancer patients with bone metastases	Bone scintigraphy
26	Tomaszewski MR et al., 2022	AI-radiomics can improve inclusion criteria and clinical trial performance	Test computational analysis of pre-accrual imaging data for patient enrichment in clinical trials for soft-tissue sarcoma (STS) patients	Retrospective analysis in a clinical trial	296 STS patients	Computed tomography (CT)
27	Riedl S et al., 2022	The effect of pegcetacoplan treatment on photoreceptor maintenance in geographic atrophy monitored by artificial intelligence-based OCT analysis	Investigate the therapeutic effect of pegcetacoplan on photoreceptor (PR) loss and thinning in geographic atrophy (GA) using AI-based OCT analysis	Post hoc analysis of a clinical trial	246 patients with GA	Spectral-domain OCT (SD-OCT)
28	Wang D et al., 2020	Evaluation of rectal cancer circumferential resection margin using faster region-based convolutional neural network in high-resolution magnetic resonance images	Explore the application of faster region-based CNN for identifying positive circumferential resection margins in high-resolution MRI	Retrospective study	240 rectal cancer patients	High-resolution MRI
29	Meng M et al., 2022	Differentiation of breast lesions on dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) using deep transfer learning based on DenseNet201	Evaluate the efficacy of deep transfer learning based on DenseNet201 model to differentiate malignant from benign lesions on breast DCE-MRI	Research study	4260 images of benign lesions, 4140 images of malignant lesions	Breast DCE-MRI
30	Xu JH et al., 2020	Application of convolutional neural network to risk evaluation of positive circumferential resection margin of rectal cancer by magnetic resonance imaging	Explore the feasibility of using faster regional convolutional neural network (Faster R-CNN) to evaluate CRM status of rectal cancer in MRI	Research study	350 patients with rectal cancer and positive CRM	Magnetic resonance imaging (MRI)

diagnosing atherosclerosis, an AI enabled quantitative coronary computed tomographic angiography was successful in reducing human errors [13]. These advancements underscore the critical role AI plays in enhancing the accuracy and reliability of medical imaging analysis, thereby supporting healthcare professionals in making informed clinical decisions [37].

Domain two: operational efficiency

AI has significantly contributed to enhancing operational efficiency.

Table 3
AI techniques, models, findings, criteria, performance, and limitations of studies.

SN	Study	AI techniques	AI model development	Key findings	Diagnostic criteria	Performance metrics	Limitations
1	Ipp E et al., 2021	EyeArt Automated DR Detection System, version 2.1.0	Developed based on analysis from February 14 to July 10, 2019	High sensitivity and specificity in detecting mtmDR and vtDR without dilation	ETDRS severity scale	Sensitivity: 95.5 % for mtmDR; Specificity: 85.0 % for mtmDR; Sensitivity: 95.1 % for vtDR; Specificity: 89.0 % for vtDR	Limited to specific forms of DR, potential bias in population selection
2	Luo H et al., 2019	Gastrointestinal Artificial Intelligence Diagnostic System (GRAIDS)	Images used to develop and test GRAIDS	High diagnostic accuracy in identifying upper gastrointestinal cancers, comparable to expert endoscopists	Histologically proven malignancies of upper gastrointestinal cancer lesions	Accuracy: 0.955; Sensitivity: 0.942; Positive Predictive Value: 0.814; Negative Predictive Value: 0.978	Limited validation in diverse settings, potential bias in image selection
3	Waldstein SM et al., 2020	Artificial intelligence algorithms for 3D segmentation of drusen and hyperreflective foci (HRF)	Validated AI algorithms for automatic segmentation of drusen and HRF in OCT volumes	Drusen and HRF showed distinct topographic patterns and were effective biomarkers of disease progression in AMD	Morphologic patterns in AMD progressing to MNV and MA	Not specified	Limited by the study design and specific patient population
4	Abadia AF et al., 2022	Artificial intelligence convolutional neural networks (CNN)	AI convolutional neural network prototype used for evaluation	AI showed similar sensitivity to an experienced radiologist in detecting lung nodules and helped detect previously missed nodules	Detection of lung nodules in complex lung disease patients	AI sensitivity: 67.7 %; AI correctly classified patients with nodules present/absent with a sensitivity of 96.1 %	Limited by the retrospective nature and the specific population of patients with complex lung disease
5	Yang X et al., 2022	AI system based on EUS images	Developed using 10,439 EUS images	Increased total accuracy of endosonographers in diagnosing GISTs or GILs; AI improved diagnostic accuracy	GISTs and GILs diagnosed via EUS	Total accuracy of endosonographers increased to 78.8 % with AI assistance	Limited to specific types of gastrointestinal tumors
6	Jonas R et al., 2021	AI enabled quantitative coronary computed tomographic angiography (AI-QCT)	AI software for quantification of APCs on CCTA	Identified unique atherosclerotic plaque characteristic signatures that differ by age and degree of stenosis	Coronary stenosis and atherosclerotic plaque characteristics	Not specified	Analysis limited to participants from the CREDENCE trial
7	Zhang Y et al., 2022	M-RCNN segmentation algorithm	M-RCNN compared to other methods	High accuracy of AI algorithm in diagnosing small liver cancer; high expression of EZH2 and decreased expression of p57 in cancer tissues	Small liver cancer diagnosed via multimodal ultrasound	Higher accuracy and average precision of M-RCNN	Limited to specific cancer type and imaging modality
8	Schwendicke F et al., 2022	AI-based software (dentalXrai Pro 1.0.4)	AI-based detection compared to non-AI	AI-supported detection more sensitive but led to more invasive treatments; similar effectiveness and cost compared to non-AI	Proximal caries detected via bitewings	AI and non-AI showed identical effectiveness and nearly identical costs	Limited to caries detection in dental practice
9	Fan X et al., 2022	Active contour segmentation algorithm	AI-based active contour segmentation algorithm	High effectiveness of AI-based CT imaging in analysing treatment effect of LDH; scalpel treatment more effective	Lumbar disc herniation	High effectiveness in diagnosing LDH and analysing treatment effect	Limited to lumbar disc herniation and scalpel treatment
10	Upton R et al., 2022	Machine learning classifier	Ensemble machine learning classifier	Automated analysis possible using AI; automated classifications improved accuracy, inter-reader agreement, and reader confidence	Severe coronary artery disease on invasive coronary angiography	High specificity and sensitivity in training dataset	Limited to severe coronary artery disease detection
11	Hwang EJ et al., 2023	AI-based computer-aided detection (AI-CAD)	Commercial AI-CAD system (Lunit INSIGHT CXR)	AI-CAD did not improve sensitivity and false-positive rate of CR interpretation for diagnosing acute thoracic disease	Acute thoracic diseases	No significant difference in sensitivity and false-positive rate with AI-CAD	Limited to acute respiratory symptoms in ED setting
12	Menzies SW et al., 2023	Mobile phone-powered AI instruments	7-class AI algorithm and ISIC AI algorithm	AI algorithm equivalent to specialists' diagnoses; mobile phone-powered AI accurate for diagnosis but requires careful execution for management decisions	Pigmented skin lesions	AI diagnoses equivalent to or superior to novices' ones	Limited to pigmented skin cancer diagnosis and management in a clinical setting
13	Du Q et al., 2022	FCM clustering algorithm	FCM algorithm compared to traditional methods	Improved detection with FCM algorithm; PDCA home nursing showed	Diabetic nephropathy diagnosis and management	Higher coverage and reduced running time with FCM	Specific to diabetic nephropathy

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Table 3 (*continued*)

SN	Study	AI techniques	AI model development	Key findings	Diagnostic criteria	Performance metrics	Limitations
				superior curative effect and quality of life improvement			
14	Kundisch A et al., 2021	AI ICH detection software (AIDOC)	AI analysis compared to initial radiology reports	AI algorithm detected additional ICHs, missed 12.4 % and overcalled 1.9 % of ICHs; better detection rate than radiology reports	Intracranial hemorrhages detection	AI increased ICH detection by 12.2 %	Limited to high-volume centers
15	Park A et al., 2019	3D convolutional neural network (HeadXNet)	HeadXNet model for aneurysm segmentation	AI-augmentation resulted in improved sensitivity, accuracy, and interrater agreement in diagnosing aneurysms	Aneurysm presence	Improved clinician performance with AI assistance	Limited to intracranial aneurysms
16	Qi C et al., 2022	Convolutional neural networks (IQA-CNNs)	IQA-CNNs for subjective and objective assessments	AI-driven system comparable to senior physicians; provides subjective visual scores and objective image metrics	Image quality assessment	Comparable to senior physician performance	Specific to [18F]FDG PET/CT imaging
17	Lipkin I et al., 2022	AI-QCT interpretation	AI-QCT for stenosis determination	AI-QCT had higher diagnostic performance than MPI; AI-QCT could substantially reduce unnecessary downstream invasive testing	Obstructive coronary artery disease	Higher performance of AI-QCT compared to MPI	Limited to coronary CTA and myocardial perfusion imaging
18	Nam JG et al., 2023	AI-based CAD software	Commercial AI-based CAD system	AI improved detection of actionable lung nodules and malignant lung nodules; comparable false-referral rates to manual assessment	Actionable lung nodules	Improved detection rates with AI assistance	Specific to health checkup participants
19	Backhaus SJ et al., 2022	Automated CMR analysis	Developed new algorithm for CMR analysis	Automated GLS and GCS predicted MACE with accuracy similar to manual analysis	Acute myocardial infarction (AMI)	High agreement between automated and manual strain assessments	Limited to AMI patients
20	Sun L et al., 2023	Convolutional neural network (CNN)	Developed lightweight MRI image intelligent segmentation model (LT-RCNN)	AI model accurately located and segmented AIS lesions; early rehabilitation altered inflammatory factor levels and EPC mobilization	Acute ischemic stroke (AIS)	High segmentation accuracy and sensitivity	Specific to AIS patients
21	Kahn A et al., 2022	IRIS algorithm	Implemented IRIS algorithm for real-time alerts	IRIS-enhanced VLE identified 100 % of dysplastic areas, compared to 76.9 % with unenhanced VLE	Dysplasia detection	Reduced interpretation time and improved dysplasia detection	Specific to Barrett's Esophagus patients
22	Martinez-Gutierrez JC et al., 2023	AI-enabled LVO detection	AI algorithm for real-time LVO detection	AI implementation reduced door-to-groin time by 11.2 min and initiation of CT scan to EVT start time by 9.8 min	Large vessel occlusion (LVO) ischemic stroke	Reduction in EVT treatment times	Limited to patients with stroke undergoing EVT
23	Yin HL et al., 2023	Deep learning models	Developed models based on contrast-enhanced T1-weighted, DWI, and T2-weighted imaging	Combined diagnosis of MRI-based models showed high performance in differentiating TNBC from fibroadenoma	Triple-negative breast cancer (TNBC)	Comparable performance to senior radiologists	Limited to TNBC and fibroadenoma
24	Lee GW et al., 2022	Convolutional neural network (CNN)	Developed CNN algorithm for radiographs	Accuracy of 87.1 % and AUC of 0.864 in detecting CSM	CSM diagnosis	Accuracy and AUC	Limited to patients visiting a spine center
25	Reza M et al., 2021	Automated Bone Scan Index (aBSI)	Utilised EXINIboneBSI software	aBSI increase significantly associated with overall survival; higher aBSI indicates worse prognosis	Prostate cancer with bone metastases	aBSI changes associated with overall survival	Retrospective and specific to a clinical trial population
26	Tomaszewski MR et al., 2022	AI-Radiomics	Extracted 164 radiomics features; used deep learning-based segmentation	Identified radiomics feature (SRE) as a predictor for patient enrichment; significant survival difference between treatment groups	Metastatic STS	Radiomics score associated with survival	Specific to STS patients in a clinical trial
27	Riedl S et al., 2022	Deep learning-based algorithms	Fully automated, deep learning-based segmentation	Pegcetacoplan treatment reduced PR loss and thinning in GA; AI-based OCT quantification ideal for monitoring disease activity and efficacy	GA because of age-related macular degeneration	Quantified PR loss/ maintenance	Specific to patients with GA

(*continued on next page*)

Table 3 (*continued*)

SN	Study	AI techniques	AI model development	Key findings	Diagnostic criteria	Performance metrics	Limitations
28	Wang D et al., 2020	Faster region-based CNN	Faster R-CNN model training with MRI images	Accuracy of 0.932 in determining CRM status, with the area under the ROC curve of 0.953	Positive circumferential resection margin	Accuracy, sensitivity, specificity, ROC curve, AUC	Single-center study
29	Meng M et al., 2022	Deep transfer learning (DTL) based on DenseNet201 model	DTL model training with DCE-MRI images	The S2 strategy exhibited the highest accuracy (98.01 %) in the testing set	Malignant vs. benign breast lesions	Accuracy, precision, recall rate, f1 score, AUROC	Specific to breast lesions
30	Xu JH et al., 2020	Faster regional convolutional neural network (Faster R-CNN)	Faster R-CNN training with MRI images	Accuracy of 0.884 in determining CRM status	Positive circumferential resection margin	Accuracy, sensitivity, specificity, ROC curve, AUC	Specific to rectal cancer patients

Table 4
Mapping the 30 studies to the 4 diagnostic imaging domains and 8 functions.

SN	Study	Domain 1: Enhanced Image Analysis		Domain 2: Operational Efficiency		Domain 3: Predictive and Personalised Healthcare		Domain 4: Clinical Decision Support	
		Function 1: Enhanced Image Analysis	Function 2: Reducing Human Error	Function 3: Efficiency and Speed	Function 4: Cost-Effectiveness	Function 5: Predictive Analytics	Function 6: Personalised Medicine	Function 7: Assistance in Complex Procedures	Function 8: Integration with Other Technologies
1	Ipp E et al., 2021	✓							
2	Luo H et al., 2019	✓							
3	Waldstein SM et al., 2020	✓							
4	Abadia AF et al., 2022	✓		✓					
5	Yang X et al., 2022	✓					✓		
6	Jonas R et al., 2021		✓						
7	Zhang Y et al., 2022	✓							
8	Schwendicke F et al., 2022			✓					
9	Fan X et al., 2022				✓				
10	Upton R et al., 2022							✓	
11	Hwang EJ et al., 2023			✓					
12	Menzies SW et al., 2023					✓			
13	Du Q et al., 2022					✓			
14	Kundisch A et al., 2021		✓						✓
15	Park A et al., 2019		✓					✓	
16	Qi C et al., 2022							✓	
17	Lipkin I et al., 2022					✓			
18	Nam JG et al., 2023		✓	✓				✓	
19	Backhaus SJ et al., 2022					✓			
20	Sun L et al., 2023					✓			
21	Kahn A et al., 2022							✓	
22	Martinez-Gutierrez JC et al., 2023							✓	
23	Yin HL et al., 2023					✓			
24	Lee GW et al., 2022							✓	
25	Reza M et al., 2021			✓		✓			
26	Tomaszewski MR et al., 2022					✓			
27	Riedl S et al., 2022					✓			
28	Wang D et al., 2020		✓	✓				✓	
29	Meng M et al., 2022			✓		✓			
30	Xu JH et al., 2020							✓	

✓ = Discussed domains and functions in the 30 studies.

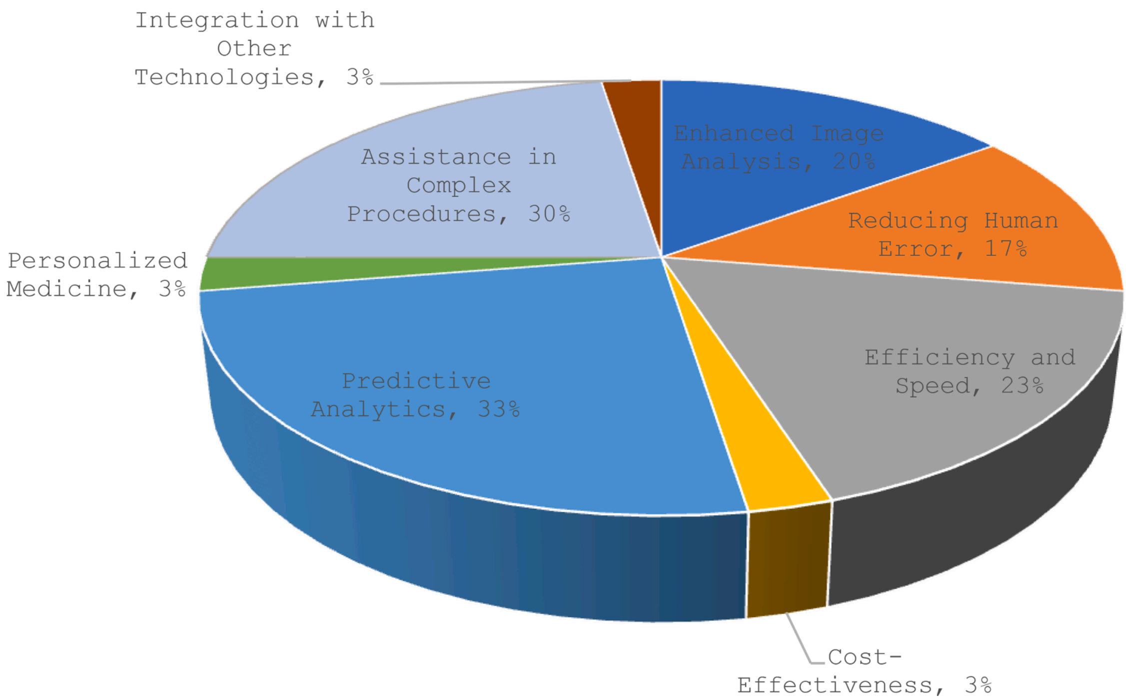

Fig. 3. AI potential contribution to diagnostic imaging.

This is evident in the areas of efficiency and speed in image interpretation and cost-effectiveness. AI's capacity to accelerate the process of reading and interpreting medical images is highlighted in several studies. For instance, AI CNNs not only matched the sensitivity of experienced radiologists but also detected 8.4 % of lung nodules that would have been missed, in patients with complex lung diseases, thereby increasing the speed and efficiency of diagnostic processes [10]. Similarly, AI's proficiency in processing and analysing large volumes of data rapidly, using AI-supported detection methods, was demonstrated in a study involving cost-effectiveness analysis for caries detection. This emphasised the substantial time-saving benefits brought about by AI in dental imaging analysis, where the AI system significantly reduced the time required for image interpretation, underscoring the efficiency gains in dental diagnostics [19]. Another study focusing on AI-assisted interpretation of chest radiographs for patients with acute respiratory symptoms in an emergency department setting underlines the potential of AI to improve the speed of diagnosis. This research showed that AI-based computer-aided detection did not significantly enhance the sensitivity or false-positive rate of radiograph interpretation. However, the use of AI in this context could potentially streamline workflow and reduce the time to diagnosis, which is crucial in emergency medical settings [18].

In terms of reducing healthcare costs, a study on the use of AI-based CT imaging in the diagnosis of lumbar disc herniation by scalpel treatment demonstrates how AI can contribute to cost-effectiveness in healthcare. The study found that CT images based on the AI algorithm could analyse the treatment effect of lumbar disc herniation more effectively, suggesting that the use of AI in diagnostic imaging could reduce errors and misdiagnoses, thereby potentially lowering the costs associated with unnecessary treatments and follow-up diagnostic procedures [20]. In summary, these studies collectively highlight the significant role of AI in enhancing operational efficiency in the medical field. By speeding up the process of reading and interpreting medical images and reducing healthcare costs through improved efficiency and accuracy, AI is proving to be an invaluable asset in contemporary healthcare practices [38].

Domain three: predictive and personalised healthcare

Predictive and Personalised Healthcare focuses on leveraging historical data and patient-specific characteristics to improve healthcare outcomes through predictive analytics and personalised medicine. Predictive analytics in healthcare utilizes historical data to forecast potential health issues, enabling early diagnosis and timely interventions [5]. In a recently published study, the use of deep learning was demonstrated to predict overall survival in prostate cancer patients. The Automated Bone Scan Index, derived from bone scintigraphy images, could identify patients at higher risk, potentially guiding more targeted treatment approaches [27]. Utilising cardiovascular magnetic resonance imaging data, deep learning techniques were applied to evaluate myocardial strain, aiding in risk stratification following acute myocardial infarction. This approach offers a more efficient, automated method for assessing heart function [24]. Research work was also conducted to explore the impact of home nursing on circulating endothelial progenitor cell mobilization in patients with diabetic nephropathy, using a lightweight AI algorithm for MRI image processing. This approach could enhance patient monitoring and treatment effectiveness [25].

In 2022, a study evaluated the use of AI in interpreting coronary CT angiograms, comparing its performance with myocardial perfusion imaging for detecting obstructive coronary artery disease. AI showed higher diagnostic performance, potentially improving patient selection for invasive procedures [23]. In 2023, Menzies and colleagues conducted a multicentre trial comparing AI and clinician performance in diagnosing pigmented skin cancer. Using mobile phone-powered AI, the study found AI diagnoses matched specialists in accuracy, yet necessitated careful consideration for management decisions, emphasising AI's potential and limitations in clinical applications for skin cancer [22]. In 2022, Du Q et al. evaluated the impact of functional MRI under an AI clustering algorithm on plan-do-check-action home nursing for diabetic nephropathy patients. The study revealed that the AI algorithm enhanced detection accuracy and the plan-do-check-action approach notably improved patient outcomes and quality of life [21]. In 2023, Yin HL et al. conducted a retrospective study using deep learning AI models on multiparametric MRI to differentiate triple-negative breast cancer from benign fibroadenoma. The combined diagnosis approach demonstrated high effectiveness, matching the performance of senior radiologists [26]. Similarly, Tomaszewski et al. conducted a retrospective analysis in a clinical trial to assess AI-radiomics in improving patient selection for soft-tissue sarcoma treatments. By extracting 164 radiomics features from CT scans and using deep learning segmentation, they identified the feature, significantly correlating with patient survival and treatment outcomes [28].

Studies also demonstrated the effectiveness of AI in enhancing diagnostic accuracy, where Riedl et al. successfully quantified photoreceptor loss in macular degeneration, while Meng et al. accurately differentiated between malignant and benign breast masses. These findings underscore AI's potential in improving disease detection and monitoring, signifying a pivotal step in advanced medical diagnostics [29,30]. AI-supported personalised medicine, leveraging patient-specific characteristics for tailored diagnostic approaches, was explored using CNNs to evaluate rectal cancer circumferential resection margins. A study highlights the potential of AI in analysing individual patient data from high-resolution MRI images to predict surgical outcomes. By considering unique tumour characteristics and their proximity to crucial anatomical structures, this approach aids in personalised surgical planning, ensuring better patient-specific treatment strategies [11].

Domain four: clinical decision support

Clinical Decision Support (CDS) systems play a crucial role in enhancing healthcare delivery by aiding medical professionals in decision-making processes. Two key functions within this domain are Assistance in Complex Procedures and Integration with Other Technologies. Assistance in Complex Procedures involves utilising AI to provide precise imaging, crucial in guiding doctors during complex medical procedures [39]. In 2022, Upton et al. conducted a multicentre study to establish if AI could automate stress echocardiography analysis for detecting severe coronary artery disease. Using a machine learning classifier, they found that AI not only made automated analysis possible but also improved diagnostic accuracy, inter-reader agreement, and clinician confidence [31]. In 2019, Park et al. developed the HeadXNet model, a 3D CNN, to segment aneurysms in head CT angiography imaging. This diagnostic study demonstrated that AI augmentation improved sensitivity, accuracy, and interrater agreement in diagnosing intracranial aneurysms, enhancing clinician performance through AI assistance [16]. In 2022, Qi C et al. developed an AI-driven image quality assessment system for whole-body PET/CT imaging. Utilising CNNs, this developmental study demonstrated that the AI system's performance was comparable to that of senior physicians, providing both subjective visual scores and objective image metrics [32].

In 2023, Nam et al. conducted a randomised controlled trial to assess if AI-based computer aided detection software could enhance the detection of actionable lung nodules in chest radiographs. Enrolling 10,476 health checkup participants, the study found that AI significantly improved the detection of actionable and malignant lung nodules, maintaining comparable false-referral rates to manual assessments [15]. In 2022, Kahn et al. assessed the impact of the Intelligent Real-time Image Segmentation (IRIS) AI algorithm on dysplasia detection in Barrett's Oesophagus using a randomised cross-over study involving 133 patients. They found that IRIS-enhanced volumetric laser endomicroscopy (VLE) identified 100 % of dysplastic areas, significantly outperforming unenhanced VLE, which detected 76.9 %, thus reducing interpretation time and enhancing detection accuracy [33]. In 2023, Martinez-Gutierrez et al. conducted a cluster randomised stepped-wedge trial to evaluate if automated CT angiogram interpretation could enhance in-hospital endovascular thrombectomy (EVT) workflows for stroke patients. They found that AI-enabled large vessel occlusion (LVO) detection significantly reduced door-to-intervention time by 11.2 min and the time from CT initiation to EVT start by 9.8 min in 243 patients with LVO stroke, thereby streamlining EVT treatment times [34].

In 2022, Lee et al. developed a convolutional neural network (CNN) to detect cervical spondylotic myelopathy using lateral cervical spine radiographs in a retrospective study. The CNN demonstrated an 87.1 % accuracy and decision support capability and an AUC of 0.864 in diagnosing spondylotic myelopathy among 207 patients visiting a spine center [35]. In 2020, Wang et al. conducted a retrospective study to explore the use of a faster region-based convolutional neural network (CNN) for identifying positive circumferential resection margins (CRM) in high-resolution MRI images of rectal cancer. The study, involving 240 patients, showed an accuracy of 0.932 and an area under the ROC curve of 0.953, demonstrating the model's effectiveness in CRM determination and decision support [17]. Similarly, In 2020, Xu et al. explored the feasibility of using a faster regional convolutional neural network (Faster R-CNN) for evaluating circumferential resection margin (CRM) status in rectal cancer using MRI. Involving 350 rectal cancer patients with positive CRM, the study achieved an accuracy of 0.884 in determining CRM status, indicating the model's effectiveness in rectal cancer diagnosis [36]. Integrating AI with other technologies, some studies demonstrated the effectiveness of integration of AI with radiology in detecting intracranial haemorrhages (ICH) on head CT scans. Utilising AI ICH detection software (AIDOC), one research study analysed emergency HCT scans from multiple centres. The AI algorithm identified additional ICH instances, enhancing detection rates by 12.2 %. This integration highlights AI's role in augmenting human expertise, especially in high-volume, time-sensitive clinical environments like trauma centers, offering a comprehensive approach to patient diagnosis and care [14].

Limitations and recommendations

The integration of AI in diagnostic imaging, while promising, presents several ethical dilemmas and challenges that necessitate careful consideration. The risk of algorithmic bias, for instance, could perpetuate disparities in healthcare outcomes, exacerbating inequities among different patient populations. It is imperative to ensure the principles of transparency, fairness, and accountability are embedded within AI decision-making frameworks to mitigate such risks [40,41]. Moreover, the protection of patient data privacy stands as a paramount concern, given the highly personal nature of medical information. Implementing stringent data security measures is critical to maintaining patient trust and adhering to legal standards [42,43]. Moreover, the successful integration of AI technologies into existing healthcare infrastructures demands a collaborative approach, one that harmonizes the innovative capabilities of AI with the nuanced expertise of medical professionals. This balance is essential to avoid undermining the quality of patient care. Addressing these ethical considerations and operational challenges is essential for leveraging AI's full potential in diagnostic imaging responsibly and effectively [38,44].

To fully harness AI's potential in supporting diagnostic imaging, seven major recommendations are proposed. 1) Continued investment in AI research and development is essential to enhance its diagnostic capabilities and address current limitations, including refining AI algorithms for improved accuracy and reduced biases. 2) Establishing clear ethical guidelines and robust privacy frameworks is imperative to responsibly manage AI's use in healthcare and ensure the secure handling of sensitive patient data. 3) Healthcare professionals should receive adequate training to effectively integrate AI into their practices, encompassing an understanding of AI capabilities, limitations, and the interpretation of AI-generated insights. 4) A collaborative approach involving AI developers, healthcare professionals, and regulatory bodies is crucial to ensure AI tools meet clinical needs and comply with healthcare regulations. 5) Emphasising a patient-centred approach in AI development will ensure that the technology enhances the patient experience and caters to individual health needs. 6) Addressing disparities in healthcare is also critical, which includes ensuring diverse and representative data sets for AI training and addressing access issues across different populations. 7) Finally, continuous monitoring and evaluation of AI in clinical settings are necessary to assess its impact on healthcare outcomes and to identify areas for improvement.

Conclusion

AI is revolutionising diagnostic imaging, enhancing the accuracy and efficiency of medical image interpretation and significantly impacting healthcare delivery. This review highlights AI's exceptional ability to detect intricate patterns in medical images, often surpassing human capabilities, which is crucial for diagnosing complex diseases such as cancer and neurological disorders. AI's role in reducing human error, coupled with its rapid processing abilities, not only accelerates diagnostic procedures but also contributes to operational efficiency and cost-effectiveness by minimizing unnecessary repeat scans and the likelihood of misdiagnoses. Furthermore, AI's application in predictive and personalized healthcare leverages historical and patient-specific data to facilitate early disease detection and create customized treatment plans, thereby improving patient outcomes. In clinical decision support, AI aids in complex procedures and integrates with existing technologies, enhancing clinical decision-making with comprehensive health insights. AI's transformative impact on diagnostic imaging underscores its potential to advance healthcare towards more accurate, efficient, and personalized patient care.

CRediT authorship contribution statement

Mohamed Khalifa: Writing – review & editing, Writing – original draft, Supervision, Resources, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Mona Albadawy:** Writing – review & editing, Writing – original draft, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare no conflicting interests to declare regarding the publication of this manuscript.

Declaration on the use of AI in the writing process

The authors of this manuscript declare that in the writing process of this work, no generative artificial intelligence (AI) or AI-assisted technologies were used to generate content, ideas, or theories. We utilized AI solely for the purpose of enhancing readability and refining language. This use was under strict human oversight and control. After the application of AI technologies, the authors carefully reviewed and edited the manuscript to ensure its accuracy and coherence. The authors understand the potential of AI to generate content that may sound authoritative yet might be incorrect, incomplete, or biased. Considering this, the authors ensured that the manuscript was thoroughly revised by human eyes and judgment. In line with Elsevier's Authorship Policy, the authors confirm that no AI or AI-assisted technologies have been listed as an author or co-author of this manuscript. The authors fully comprehend that authorship comes with responsibilities and tasks that can only be attributed to and performed by humans, and authors have adhered to these guidelines in the preparation of this manuscript.

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