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The evolution of artificial intelligence in diagnostic imaging: Challenges and perspectives

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Summary: Objective: *To synthesize the state of the art and the impacts of artificial intelligence (AI) on medical diagnosis by analyzing performance techniques, operational efficiency and solutions in explainable artificial intelligence (XAI). Methods: This was a review of reviews (Umbrella Review) based on the PRISMA guidelines. The search was carried out in the PubMed and Scopus databases and covered the period from 2022 to 2026, resulting in the selection of ten articles.* ***Results:*** *The AI achieved an accuracy greater than 95% in classification tasks and a 30% to 50% reduction in segmentation time. in radiotherapy. The fusion of multimodal data surpasses modality models uniquely, although there are persisting standardization challenges and black box phenomena.* ***Conclusion:*** *AI is an indispensable pillar of precision medicine. Success in clinical practice depends on greater methodological rigor, greater external validation, and the adoption of models. intrinsically self-explanatory.*
Keywords: Artificial Intelligence, Diagnostics Through Images, Deep Learning.

Abstract: Objective: *To synthesize the state of the art and the impacts of artificial intelligence (AI) in diagnostic medicine by analyzing technical performance, operational efficiency, and explainable artificial intelligence (XAI) solutions.* ***Method:*** *This was an Umbrella Review based on PRISMA guidelines. The search was conducted in the PubMed and Scopus databases and covered the period from 2022 to 2026, resulting in the selection of ten articles.* ***Results:*** *The accuracy of the AI model exceeded 95% in classification tasks and a 30% to 50% reduction in segmentation time during radiotherapy. Multimodal data fusion outperforms singlemodality models, although standardization challenges and the black-box phenomenon persist.* ***Conclusion:*** *AI is an essential pillar of precision medicine. Success in clinical practice depends on greater methodological rigor, greater external validation, and the adoption of intrinsically self-explanatory models.*
Keywords: Artificial Intelligence, Diagnostic Imaging, Deep Learning.

INTRODUCTION

Medicine diagnostic methods cross an era of transformation without precedents, driven by the convergence of the exponential growth of clinical data and the maturation of artificial intelligence (AI) architectures. Once restricted in experimental settings, this tool currently manifests itself as a strategic tool in radiology, digital pathology and oncology, offering solutions for historical challenges, such as variability, interobserver fatigue, and the need for diagnoses each time more early and personalized.

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deep learning models that achieve accuracies exceeding 95% in classification tasks, the clinical implementation of these technologies is not without obstacles. On the one hand, there is the decision-making process of a machine that learns through *deep learning. While machines offer data,* such as computer-aided *learning,* the primary decision-making power remains with humans (medical specialists). That is, machines can provide data and, to some extent, point toward interpretation, but the diagnosis still rests with the specialist. Given the vast and fragmented literature on the subject, it is imperative to consolidate the most recent evidence to guide healthcare professionals and managers. This article aims to synthesize the state of the art and the impacts of AI in diagnostic medicine. Through an *umbrella review*, we seek to integrate results from multiple evidence syntheses to analyze not only the technical performance and accuracy of algorithms but also the operational efficiency, advances in precision medicine, and emerging solutions in explainable AI (XAI).

METHODS

Study Design

This Review of Reviews (*Umbrella Review*) is designed to synthesize and integrate evidence from systematic and scoping reviews on the impact of artificial intelligence (AI) on diagnostic medicine. The protocol development and results reporting followed the PRISMA (*Preferred* Standards for Modernization) guidelines. *The Reporting Items for Systematic Reviews and Meta-Analyses* were used to ensure the transparency and methodological quality of the research.

Search strategy and databases

The PubMed and Scopus databases were selected for their high indexing of high-impact journals in the areas of medical technology, radiology, and health informatics. The time frame covered the period from January 2022 to 2026, aiming to capture the most recent and disruptive advances in the field.
The descriptors were selected from MeSH (*Medical Subject Headings). Headings*) and free terms, combined using Boolean operators (“Artificial Intelligence ” OR “Deep Learning” OR “Machine Learning”) AND (“Diagnostic Imaging” OR “Radiology ” OR “Digital Pathology ”). AND (“Systematic Review” OR “ Scoping Review” OR “Meta-Analysis”).

Eligibility and selection criteria

For the composition of the research *corpus*, original studies of primary experimentation were excluded (ensuring that the analysis focused on syntheses of already consolidated evidence) and filtered by literature reviews (systematic, scoping or high-level narratives) published in high-impact

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journals and submitted to the peerreview process, *with the* thematic scope "Applications of *Machine Learning* and *Deep Learning* in Health, with emphasis on medical imaging (Magnetic Resonance Imaging, Computed Tomography, PET-Scan, Digital Pathology)", with a total of ten articles selected at the end of the exploratory search.

Of the 10 articles analyzed, 90% formally used the PRISMA methodology or its specific extensions, such as the PRISMA-ScR for scoping reviews and the PRISMA-DTA for diagnostic accuracy, conferring high statistical reliability and reproducibility to the extracted data.

The work of Tiwari et al. (2025) constitutes the only exception to the PRISMA protocol and is classified as a comprehensive narrative review; however, its inclusion is justified by its relevance in providing an update on the "state of the art" of AI in cancer treatment and diagnosis, serving as a fundamental contextual basis for the technical discussions of this study.

Data Extraction and Synthesis

The data were extracted and categorized into two main axes for comparative analysis: 1) a technical approach with emphasis on explainable AI (XAI), self-supervised learning and the integration of multimodal data (EHR + Imaging); and 2) performance metrics, focusing on clinical workflow efficiency, diagnostic accuracy and algorithmic interpretability.

The synthesis was carried out qualitatively, contrasting the conclusions of the systematic reviews with the perspectives presented in the selected narrative review. This approach allowed for a holistic and technically sound view of the current stage of AI maturity in diagnostic medicine.

RESULTS

Table 1: Characterization of the results obtained in the search by the authors, based on authorship, year, study design, methodology and results

Author	**Year**	**Study**	**Methodology**	**Results**
Khalifa and Albadawy	2024	Literature review	Systematic research (2019-2023) following guidelines PRISM in databases such as PubMed and Embase; analysis of 30 studies .	Identified four AI domains : image analysis , efficiency operational , health personalized and decision support , highlighting gain in precision .
Warren and Moustafa	2023	Revision systematic	Following PRISMA used the ASReview tool for screening . automated processing of 831 articles in neuroimaging databases .	He analyzed 22 studies . what demonstrate high Accuracy (up to 97%+) in diagnosing Alzheimer's disease using fMRI and Deep Learning models .

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De Vries and others.	2023	Literature review	Systematic research ranked in PubMed, Embase, and Web of Science for the flowchart PRISM .	It included 75 articles. on Explainable AI (XAI), concluding what methods *ad hoc* offer better transparency clinical rather than methods *post hoc* .
Kelly and others.	2022	Revision systematic (RAISE)	Methodology based in PRISMA and Cochrane Manual; evaluated radiology studies clinic published between 2015 and 2019.	It evaluated 535 articles , revealing predominance of studies retrospective analysis and the need for greater methodological rigor and external validation .
Tiwari and others.	2025	In-depth review	Analysis comprehensive application of AI concepts and architectures (ML, DL, NLP) in oncology , genomics and biopsies liquids .	He demonstrated what AI acts as one A bridge to precision medicine , improving detection . Early detection and personalized treatment .
Waves and others.	2024	Revision systematic	Accession strict to the protocols PRISMA and Kitchenham; search in 5 databases up to September 2023.	Identified 23 articles. on the LIME and SHAP frameworks, highlighting your crucial role in building trust in Alzheimer's diagnoses .
Mohsen and others.	2022	Scoping Review	He used the guidelines. PRISMAScR ; search in Embase, PubMed,	It included 34 studies , concluding that the fusion of image data with records
			Scopus and Google Scholar (20152022).	Electronic health software (EHR) surpasses modality models unique .
Huang and others.	2023	Revision systematic	Based in guidelines PRISMA ; screening of 412 studies in PubMed, Scopus and ArXiv on apprenticeship Self-reviewed (SSL).	He analyzed 79 articles , demonstrating that SSL allows what models learn from data, do not labeled , improving performance general in medical imaging .
Abd-Alrazaq and others.	2023	Revision systematic and meta- analysis	The extension followed . PRISMA-DTA for accuracy diagnostic with search in 8 electronic bases .	Analyzed 54 studies about wearable AI for depression , finding accuracy average of 0.89, but noting that technology still in stages initials .
Wenderott and others.	2024	Revision systematic and meta- analysis	Compliance with the guidelines of the declaration. PRISMA ; research in six medical databases .	It included 48 studies . originals . Although 67% report time reduction in tasks , meta- analysis no showed effects statistically significant in efficiency .

Source: Prepared by our group.

is observed that you articles they delimit your search in four areas: the studies by Khalifa & Albadawy (2024), Warren & Moustafa (2023) and Huang et al. (2023) focused on precision discoveries, while Kelly et al. (2022), Tiwari et al. (2025) and Wenderott et al. (2024) focused on implementation challenges. As noted by De Vries et al. (2023) and Vimbi et al. (2024), they address solutions of explicability to step what Mohsen et al. (2022) and Abd-Alrazaq et al. (2023) analyze new data boundaries. The thematic areas of the axes identified are analyzed in the following section.

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DISCUSSION

Recent evidence has demonstrated that artificial intelligence (AI) has ceased to be a promising theory for becoming a transformative pillar in diagnostic and therapeutic medicine. The results corroborate what the application of *deep learning* models and multimodal data processing offer substantial gains in precision and efficiency, although the transition from the laboratory environment to the workflow real clinician still faces barriers related to standardization, interpretability, and methodological rigor.

Image analysis and interpretation

The effectiveness of AI is one of the most established benefits of detecting subtle anomalies in imaging exams (X-rays, MRI, and CT scans), particularly for the analysis of complex patterns.

One example is the Gastrointestinal Artificial Intelligence Diagnostic System (GRAIDS), which was validated in a multicenter study conducted by Luo H et al. (2019); this system included more than 84,000 individuals and achieved high diagnostic accuracy (0.955), sensitivity (0.942) and precision comparable to those of experts in identifying cancerous lesions. (Khalifa & Albadawy, 2024).

Beyond accuracy, technology plays a vital role in reducing human error. By maintaining consistency independent of fatigue, AI mitigates lapses in supervision and is particularly assertive in distinguishing visually similar pathologies, such as gastrointestinal stromal tumors and leiomyomas (Khalifa & Albadawy, 2024). This performance is amplified by the use of self-revision learning (SSL), which emerges as a solution to the high cost and time of manual data labeling, allowing models to learn useful representations from large volumes of unlabeled data (Huang et al., 2023, p. 1).

Huang et al. reported that pretraining via SSL improves classification task performance by 6.35% compared to that of purely supervised models and offers practical guidelines for SSL implementation, aiming to help researchers choose the best architecture and fine-tuning strategy *for different* image modalities (2023, p. 1, 12).

Operational efficiency and cost-effectiveness

Despite technical enthusiasm, measuring efficiency in the real world is quite heterogeneous. AI dramatically accelerates image processing, which represents a vital advantage in emergencies that require agility in decision-making and treatment (Khalifa & Albadawy, 2024). However, meta-analyses indicate that time reductions are not always statistically significant due to variability in study designs and the integration of IT systems/infrastructure (Wenderott et al., 2024).

Nevertheless, most authors quantify significant time savings. According to Tiwari et al. (2025, p. 12), the system *IBM Watson for Oncology* generates treatment recommendations in 40 seconds, compared

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to the 12 to 20 minutes of the manual process. The authors also quoted the AlphaFold2 tool, which reduces costs and timelines for drug development, accelerating precision medicine (Tiwari et al., 2025, p. 21). In their systematic meta-analysis of AI efficiency in real image workflows, Wenderott et al. (2024) reported that during RT, the risk of organ contouring decreased between 30% and 50% with the use of segmentation tools. automatic.

In terms of cost-effectiveness, AI minimizes expenses by reducing the need for repeated examinations. The use of AI in CT scans for herniated discs, for example, has demonstrated the potential to reduce costs associated with unnecessary treatments (Khalifa & Albadawy, 2024, p. 9).

However, while the costs to the user/patient may be advantageous, the cost of developing new AI models in healthcare constitutes one of the main bottlenecks in the creation of large-scale labeled datasets, as it is described as an extremely laborious, expensive and time-consuming process Huang et al. (2023).

Predictive and personalized healthcare

Precision medicine represents a fundamental advancement in healthcare delivery, moving away from the traditional one-size-fits-all model toward a patient-centered approach. In this context, artificial intelligence (AI) acts as a bridge, integrating complex data to generate personalized insights that support more accurate and timely clinical decisions (Tiwari et al., 2025, p. 5). Diagnostic imaging is no longer just an automation of processes but rather a pillar that identifies specific characteristics, associating them with medical history to tailor individual treatment plans (Khalifa & Albadawy, 2024, p. 2).

The applications of the automated bone scan index include predicting survival in prostate cancer patients and developing *deep learning models* for risk stratification after myocardial infarction.

In personalized medicine, unique patient characteristics are analyzed to tailor diagnoses. The use of highresolution MRI and convolutional neural networks (CNNs) to predict surgical outcomes in rectal cancer patients by analyzing the proximity of the tumor to anatomical structures exemplifies this capability. In the context of Alzheimer's disease (AD), fMRI and CNN models demonstrate accuracies exceeding 90% (Warren & Moustafa, 2023), although the classification of early-stage disease, such as mild cognitive impairment (MCI), still requires more diverse databases.

However, for precision medicine to be effective, it is necessary to merge different data modalities.

The accuracy of a diagnostic test takes into account how well that test can correctly identify people with a particular disease and exclude people who do not have the disease. This accuracy can be estimated by comparing the results of a test, called an index test, with the results of a reference standard test. Participants in a diagnostic test study must undergo both the index test and the standard

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test so that the results of the two tests can then be compared. When there is a single target condition for dichotomous tests, the accuracy of a diagnostic test is usually calculated by the ratio of truly positive individuals to those who are truly negative in relation to false positives and false negatives. (OLIVEIRA et al., 2010, p. 2).

deep learning models achieve high levels of accuracy in established pathologies, true clinical effectiveness lies in the ability to translate these results to early and complex diagnoses, such as in Alzheimer's disease. Therefore, the integration of multiple data modalities, validated by the systematic comparison between index tests and reference standards, is what ensures that AI is not only an automated tool but also a reliable instrument for therapeutic personalization, ensuring that technological predictions translate into safe clinical decisions centered on the biological individuality of the patient.

Clinical Decision Support (CDS)

AI-based clinical decision support systems have evolved to integrate *Big Data* and *machine learning*, assisting in the optimization of treatment plans.

Models such as HeadXNet assist in the segmentation of aneurysms via cranial computed tomography angiography, improving interobserver agreement. Furthermore, data fusion is a new frontier: models that integrate images with electronic health records (EHRs) consistently outperform single-modality approaches (Mohsen et al., 2022).

This holistic view is fundamental in oncology, where AI integrates data from digital pathology, genomics, and liquid biopsies and enables real-time adaptive radiotherapy, adjusting doses as the patient's anatomy changes during treatment, in addition to guiding robotic surgeries with augmented 3D visualization (Tiwari et al., 2025, pp. 19-24).

The expansion of wearable technologies *for* mental health monitoring also offers potential for continuous care, although these technologies still need to be validated against traditional clinical methods (Abd- Alrazaq et al., 2023).

Challenges of precision medicine: the black box of AI

A critical challenge to the adoption of precision medicine is the black box mechanism, which refers to the lack of transparency and interpretability inherent in complex artificial intelligence models, especially those of *deep learning*.

This phenomenon occurs because these algorithms extract features in an unsupervised manner; that is, they perform learning and pattern discovery without humans having previously defined assumptions or extraction rules.

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In this context, explainable artificial intelligence (XAI) has emerged, bridging the gap between medical professionals and algorithms and allowing the validation of which characteristics (such as brain regions or specific biomarkers) trigger a clinical decision (De Vries et al., 2023, p. 1; Vimbi et al., 2024, p. 1). This is because XAI allows validation of whether the model is focused on real pathological characteristics or whether it is influenced by irrelevant noise or artifacts (algorithmic bias).

Several tools for opening the black box of AI are highlighted. Frameworks such as LIME and SHAP are essential for making Alzheimer's disease models interpretable, allowing the visualization of crucial biomarkers (Vimbi et al., 2024). LIME focuses on local interpretability through perturbations in the data, while SHAP, based on game theory, offers a unified measure of the importance of features both locally and globally.

Similarly, post hoc techniques such as Grad-CAM, LRP, and DeepLIFT are emerging and are used to generate visual maps that show physicians exactly where the model is 'looking' in an MRI or CT scan. However, there is a lack of systematic evaluation of the quality of these explanations (de Vries et al., 2023). The RAISE initiative identified a high risk of bias in many studies due to a lack of external validation and a scarcity of statistical power analyses (Kelly et al., 2022).

For AI to realize its potential, the scientific community must prioritize methodological rigor and algorithmic transparency, ensuring that technological progress translates into real and safe benefits for patients.

De Vries et al. (2023) argue that instead of simply applying *post hoc methods* as add-ons, research should evolve toward the integration of self-explanatory (*ad hoc)* modules and the creation of reporting guidelines (such as TRIPOD-AI) that ensure the transparency and safety of AI tools in the clinic.

CONCLUSIONS

The present Review of Reviews shows that artificial intelligence has consolidated your position as an indispensable pillar in the modernization of medicine diagnosis. All the authors agree with what AI is the future of medicine. diagnostic, they are divided between what they look at internal technology (such as she learns), what they look at the disease (what she detects) and what they look at the impact. clinical (as she [it] helps the doctor and the hospital).

The evidence analyzed herein indicates that the greatest benefit of AI lies in its ability to act as a "bridge" to precision medicine, enabling highly individualized treatments and reducing operational costs through the automation of repetitive tasks and accelerated triage in emergency scenarios.

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The transition of models to purely supervised approaches requires more sophisticated methods, such as selfsupervised learning (SSL). The integration of multimodal data (EHR and imaging) has enabled a leap forward. qualitative in the detection of pathological complexes, surpassing the performance of expert humans in specific scenarios.

However, the "black box" phenomenon and the risk of algorithmic bias remain the main barriers to full and safe adoption of these methods. The emergence of explainability frameworks (XAIs), such as LIME and SHAP, demonstrates that the scientific community is actively working to make models interpretable, a crucial factor in establishing clinical confidence.

In conclusion, while the technical effectiveness of AI is undeniable, its success in clinical practice will depend on greater methodological rigor, external validation in diverse populations, and the creation of robust ethical and regulatory guidelines.

post hoc explainability methods to intrinsically self-explanatory models, ensuring that technological innovation always goes hand in hand with patient safety and medical transparency.

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DECLARATION OF THE USE OF ARTIFICIAL INTELLIGENCE (AI)

The authors declare what they used during the preparation of this article—the scientific tools artificial intelligence (AI), consensus, Gemini and NotebookLM—for the literature review and survey phase bibliographic initial drafting and text refinement, respectively—with the aim of assisting in structuring topics, correction grammatical improvement and enhancement of text fluency. in the language Portuguese. NotebookLM was used in the data analysis and synthesis stage to organize documents from the local database and facilitate correlation. different authors were cited.

You authors reiterate what the The use of such tools was limited to support technical and linguistic, being what all content intellectual process, interpretation of results and conclusions. All the patients were reviewed, validated and remain under full control. responsibility and ethical and scientific principles of the authors.

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