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Artificial Intelligence in Diagnostic Imaging: A Meta-Analysis On Impacts on Early Diagnosis

Artificial Intelligence In Medical Imaging: A Meta-Analysis On Impacts In Early Diagnosis

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Summary

Artificial intelligence (AI) has profoundly transformed radiology and diagnostic imaging, offering computational tools capable of identifying patterns with high accuracy. This meta-analysis synthesizes the findings of three scientific studies indexed in SciELO, covering the use of machine learning and deep learning algorithms in the diagnosis of eye diseases, pulmonary nodules, breast cancer, and various lesions in imaging exams. The analyzed studies demonstrate that systems based on convolutional neural networks (CNNs) can achieve diagnostic accuracies equal to or greater than those of human experts in specific visual pattern recognition tasks. The study by Abed and Al-Bakry (2024) demonstrated 99.9% accuracy in classifying eight eye diseases through fundoscopy. The works of Santos et al. (2019) and Koenigkam-Santos et al. (2019) consolidate the theoretical foundations of AI applied to radiology, addressing everything from computer-assisted diagnosis to radiomics and precision medicine. The integrated analysis of these findings points to consistent benefits in increasing diagnostic sensitivity, reducing false negatives, and optimizing clinical workflow, especially in cancer screening. It is concluded that AI represents an essential complementary resource to the work of the radiologist, with the potential to expand access to early diagnosis, although further multicenter studies with prospective data are still needed for validation in diverse clinical scenarios.

Keywords: Artificial intelligence. Image diagnosis. Deep learning. Early diagnosis. Radiology.

Abstract

Artificial intelligence (AI) has profoundly transformed radiology and diagnostic imaging, offering computational tools capable of identifying patterns with high accuracy. This meta-analysis synthesizes the findings of three scientific studies indexed in SciELO, covering the use of machine learning and deep learning algorithms in the diagnosis of eye diseases, pulmonary nodules, breast cancer, and various lesions in imaging exams. The analyzed studies demonstrate that systems based on convolutional neural networks (CNNs) can achieve diagnostic accuracies equal to or greater than those of human experts in specific visual pattern recognition tasks. The study by Abed and Al-Bakry (2024) demonstrated 99.9% accuracy in classifying eight eye diseases through fundoscopy. The works of Santos et al. (2019) and Koenigkam-Santos et al. (2019) Consolidate the theoretical foundations of AI applied to radiology, addressing everything from computer-assisted diagnosis to radiomics and precision medicine. The integrated analysis of these findings points to consistent benefits in increasing diagnostic sensitivity, reducing falsehood negatives, and optimizing clinical workflow, especially in cancer screening. It is concluded that AI represents an essential complementary resource to the work of the radiologist, with the potential to expand access to early diagnosis, although further multicenter studies with prospective data are still needed for validation in diverse clinical scenarios.

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1. INTRODUCTION

Artificial intelligence (AI) is a branch of computer science dedicated to development of systems capable of simulating human cognitive abilities, including perception, learning, reasoning, and decision-making. In the field of In medicine, AI has emerged as one of the most impactful technological innovations. especially in the context of diagnostic imaging, where computational algorithms Radiology, by its very nature, is playing an increasingly important role in the early detection of diseases. highly dependent on visual interpretation, it becomes a particularly complex domain. fertile ground for the application of these technologies.

In recent years, the advent of machine learning and, especially deep learning based on neural networks. Convolutional nanowires (CNNs) have enabled computerized systems to process volumes. massive medical imaging systems with diagnostic accuracy comparable to or superior to that of Human specialists in specific tasks. These technological achievements have been documented in various scientific publications indexed in databases. international, demonstrating applications ranging from nodule detection from lung and breast lesions to the diagnosis of eye diseases through Eye background images.

Given this scenario, the present meta-analysis aims to synthesize and analyze critically examine the findings of three scientific studies indexed in SciELO, which address, From different perspectives, the impact of AI on medical imaging diagnostics, with a focus in early diagnosis. These are: the article by Abed and Al-Bakry (2024), published in the Journal of Applied Research and Technology, which proposes a CNN-based system for Classification of eight eye diseases based on fundoscopy images; the work of Santos et al. (2019), published in Radiologia Brasileira, which conducts a review Comprehensive conceptual overview of AI, machine learning, and computer-aided diagnostics. Computer and radiomics from the perspective of precision medicine; and the editorial article by

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Koenigkam-Santos et al. (2019), also in Radiologia Brasileira, which discusses the potential Transformative AI in everyday radiological practice.

The rationale for this meta-analysis lies in the fact that, although advances While individual studies in AI applied to medicine are not widely documented, there is a need integrated analyses that allow for the evaluation of consistencies, divergences, and gaps in Knowledge across different approaches and clinical contexts. Understanding the state Current knowledge of this technology is essential to guide its responsible implementation and to inform healthcare professionals, managers, and researchers about the limits and potential of these tools.

2. THEORETICAL FRAMEWORK

2.1 Artificial Intelligence and Deep Learning in Medical Imaging

The application of AI to diagnostic medicine has roots in the 1960s, when... The first clinical decision support systems were proposed. However, it was from the second half of the 2010s, with the development of infrastructure high-performance computing and the availability of large databases of Annotated medical images, which the field experienced exponential growth. CNNs, deep learning architectures specifically designed for the Visual data processing has proven particularly effective in extraction. Automatic selection of relevant features in medical images without the need for... manual attribute engineering (Santos et al., 2019).

Deep learning differs fundamentally from traditional systems of computer-aided diagnosis (CAD), which relied on established rules. manually by experts. In deep neural networks, the system learns itself. hierarchical representations of the data during the training process, becoming capable of identifying subtle visual patterns that would escape human perception. This The paradigm has brought significant gains in accuracy in tasks such as detection of Tumors, lesion classification, and segmentation of anatomical structures.

2.2 Clinical Applications and Impact on Early Diagnosis

The clinical applications of AI in diagnostic imaging cover virtually all areas. specialties in radiology. In oncology, AI algorithms have been employed in Early detection of breast cancer through mammograms, identification of lumps.

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pulmonary lesions in computed tomography scans and characterization of liver lesions in Magnetic resonance imaging. In ophthalmology, systems based on deep learning have demonstrated outstanding performance in the diagnosis of diabetic retinopathy, glaucoma and age-related macular degeneration from fundoscopy images (Abed and Al-Bakry, 2024).

According to Koenigkam-Santos et al. (2019), the possibilities of applying AI in Radiology includes the use of algorithms for patient flow and the definition of protocols. imaging, synthetic image generation, quality control, dose control radiation, computer-assisted diagnosis, automatic lesion detection, Automatic interpretation of findings and radiomics. This diversity of applications It highlights the transformative potential of technology, which goes far beyond simple... Replacing radiologists with automated systems.

The concept of radiomics, which consists of extracting a large volume of features. Quantitative analysis of medical images through computational algorithms expands the Diagnostic capabilities beyond what the human eye can perceive. When associated with radiogenomics, which correlates this image data with information Genetics opens a new frontier for precision medicine, in which each patient You can receive individualized diagnoses and treatments based on biomarkers. specific ones identified in the images (Santos et al., 2019).

2.3 Limitations, Ethical Challenges and Perspectives

Despite the documented advances, the implementation of AI in diagnosis by The image faces considerable challenges. Among them, the need to stand out. large volumes of data labeled by experts for training the models, the difficulty of generalizing algorithms trained on a population to other contexts distinct clinical aspects, issues of privacy and security of patient data, and the medico-legal aspects related to liability for reports generated or assisted by AI systems. Issues of transparency and interpretability of algorithms — the so-called "black box" problem — also represent barriers to Widespread clinical adoption.

From an ethical standpoint, it is crucial to recognize that AI systems for diagnosis The imaging techniques are not intended to replace the radiologist, but rather to enhance their expertise.

capabilities and to optimize clinical workflow. The clinicoradiological correlation, which It integrates data from medical history, individual risk factors, physical examination, and context. Clinical responsibility remains the exclusive domain of the medical professional. According to As established by the literature, AI tools cannot issue expert reports or make pronouncements. Diagnostic responsibility rests with the physician, who makes the final decision.

3. MATERIALS AND METHODS

This meta-analysis followed a systematic approach for identification, selection, and analysis. Critique of the included studies. The bibliographic search was conducted in the SciELO database. (Scientific Electronic Library Online), focusing on publications in the fields of radiology, Diagnostic imaging and artificial intelligence. Three studies were selected that, in Together, they offer a comprehensive perspective on the topic, combining aspects theoretical-conceptual frameworks, literature reviews, and experimental studies with empirical data.

The inclusion criteria adopted were: (1) publication in a journal indexed in SciELO; (2) approach to the topic of artificial intelligence applied to image diagnosis; (3) relevance to the objective of evaluating the impact of these technologies on diagnosis. early; and (4) availability of the full text in electronic format. These were not No filters were applied to restrict access by language or specific period, although all studies The selected works must be recently published, between 2019 and 2024.

The three selected articles were: (i) Abed, ZN and Al-Bakry, AM (2024). "Diagnose eyes diseases using deep learning algorithms". Journal of Applied Research and Technology, v. 22, no. 6, pp. 834–845 — experimental study that proposes and evaluates a CNN system for Classification of eye diseases into eight categories from the ODIR dataset with 5,000 (i) fundoscopy images; (ii) Santos, MK et al. (2019). "Artificial intelligence, machine learning, computer-aided diagnosis and radiomics: advances in imaging towards precision medicine". Radiologia Brasileira — comprehensive review of main AI concepts and tools applied to radiology; and (iii) Koenigkam-Santos, M. et al. (2019). "Artificial intelligence, radiology, precision medicine and medicine "Personalized." Brazilian Radiology — an editorial article that contextualizes the impact of AI in radiology and discusses perspectives for clinical practice.

The data analysis was performed through a complete reading of the texts, extraction of the main contributions, identification of convergences and divergences between the studies, and a narrative synthesis of the findings. Aspects such as the methodology employed were evaluated, Study populations, reported performance metrics, clinical applications The methodological quality is as follows: the issues addressed and limitations acknowledged by the authors themselves. The studies were evaluated based on criteria of clarity in the description of the methods. adequacy of statistical analyses and consistency of conclusions with the data presented.

4. RESULTS AND DISCUSSION

An integrated analysis of the three selected studies allows us to identify points of convergence. important points regarding the role of artificial intelligence in diagnostic imaging, as well as complementary aspects that, together, offer a comprehensive view of the state. of art in this area. The results are presented in an organized manner, followed by Critical discussion of the findings.

The study by Abed and Al-Bakry (2024) represents the most quantitative contribution of this meta-analysis, presenting empirical performance data of a system of Classification of eye diseases based on CNNs. Using the ODIR dataset, composed based on 5,000 fundoscopy images representing eight classes of diseases — including glaucoma, diabetic retinopathy, cataracts, macular degeneration, and pathological myopia— The model proposed by the authors achieved accuracy, precision, recall, and F1 score of 99.9%. This result surpasses most models reported in the literature for the same [objective/object]. dataset, surpassing previous approaches such as that of Khan et al. (2022), which It obtained 94.03% for binary classification glaucoma versus cataract with architecture. VGG19, and that of Shamsan et al. (2023), which achieved 98.5% with a hybrid architecture. DenseNet-121 and MobileNet.

The methodological process adopted by Abed and Al-Bakry (2024) included five steps. sequential: data collection, splitting the training set (70%) and test set (30%), pre-processing of images (conversion to grayscale, equalization of histogram, blur, and resizing), feature extraction with algorithms SIFT and GLCM to reduce redundant information, and application of the CNN classifier. properly speaking. This detailed pipeline highlights the necessary methodological care. for the development of reliable AI systems in medical contexts. Accuracy The reported exceptional figure, while significant, should be interpreted with caution, since

The authors acknowledge limitations related to the small sample size for some rare diseases in the dataset, which may compromise the generalization of A model for more diverse clinical populations.

In turn, the work of Santos et al. (2019) offers a theoretical contribution and An indispensable concept for understanding the mechanisms by which AI operates in Diagnostic imaging. The authors describe the principles of analysis in detail. of digital medical images, from grayscale matrix representations and Segmentation of anatomical structures up to feature extraction using histograms. co-occurrence matrices of gray levels and other quantitative metrics that These constitute the basis of radiomics. This theoretical foundation is essential for... healthcare professionals need to understand not only what AI systems do, but how they do it, allowing for a more informed critical evaluation of the results generated. through these tools.

Santos et al. (2019) highlight that the exponential increase in the number of tests of The resulting images, combined with the greater accuracy and complexity of diagnostic methods Available data has created a growing challenge for radiologists: processing a volume of such data. unprecedented availability of information in a limited timeframe. AI systems emerge in this context, not as substitutes for the expert, but as instruments that broaden their understanding. processing power allows them to identify subtle patterns imperceptible to the human eye. and provide objective quantifications of imaging parameters relevant to prognosis and therapeutic response. Radiomics, by extracting hundreds or thousands of Characteristics of a single image allow for the identification of prognostic biomarkers. which makes each patient unique and each diagnosis more accurate.

The article by Koenigkam-Santos et al. (2019) complements this perspective with a Analysis of the impact of AI on everyday radiological practice and the transformations that occur. They are emerging as specialists. The authors listed several practical applications already in Development or implementation: algorithms for optimizing patient flow. Automated definition of examination protocols, generation of synthetic images for Training and testing of models, automatic quality control and radiation dose, real-time computer-assisted diagnosis, automatic detection and classification of injuries, and assisted generation of radiological reports. This plurality of applications

This demonstrates that AI in radiology goes far beyond simple image classification. permeating all stages of the clinical workflow.

With regard to early diagnosis, which is the central focus of this meta-analysis, All three studies converge on a common conclusion: AI has the potential to elevate substantially improve diagnostic sensitivity in screening programs, Especially in the fields of oncology and ophthalmology, early detection is crucial. for the prognosis of diseases such as breast cancer, lung cancer and diabetic retinopathy, in which treatment initiated in early stages is associated with significantly higher survival rates and functional preservation superiors. As Koenigkam-Santos et al. (2019) argue, the possibility of Increasing the number of patients screened with AI could represent concrete advances. early diagnosis for many historically under-screened populations limitations in access to specialists.

A critical analysis of the three studies also reveals methodological differences. important. While Abed and Al-Bakry (2024) present experimental data with objective performance metrics, the articles by Santos et al. (2019) and Koenigkam-Santos et al. (2019) adopt narrative and editorial review approaches, respectively, without presenting primary data. This methodological heterogeneity is a limitation. inherent to this meta-analysis and reflects the diversity of types of evidence available in the literature on the subject. For future meta-analyses, it would be desirable to inclusion of a greater number of experimental studies with comparative data of performance between AI systems and human experts, preferably derived from controlled clinical trials and multicenter studies with validation. external.

Another relevant point of convergence between the studies is the recognition that the Integrating AI into radiological practice requires continuous adaptation from professionals. Santos et al. (2019) argue that the radiologist of the future will need to develop skills in data analysis and interpretation of results produced by algorithms, in addition to traditional diagnostic skills. Koenigkam-Santos et al. (2019) reinforce this perspective by highlighting that radiology societies International organizations, such as the Radiological Society of North America (RSNA), have already incorporated it.

AI as a central theme in their conferences and they have created specific journals dedicated to it. the theme, signaling the inevitability of this transformation in the specialty.

FINAL CONSIDERATIONS

This meta-analysis demonstrated, through a critical synthesis of three studies Scientific studies indexed in SciELO indicate that artificial intelligence represents an advance. Technological advancement with consistent and growing impact on medical diagnostic imaging, with This is especially relevant for the early diagnosis of diseases with high morbidity and mortality.

The findings of the experimental study by Abed and Al-Bakry (2024) showed that CNN-based systems can achieve diagnostic accuracies close to 100% in classification of eye diseases based on fundoscopy images, surpassing previous approaches and demonstrating the potential of AI in ophthalmological screening. on a large scale. This result, although it should be interpreted with caution due to the Limitations of the dataset used represent a valuable proof of concept for the development of automated sorting systems that could reduce drastically reducing the impact of preventable eye diseases such as diabetic retinopathy and glaucoma.

The reviews by Santos et al. (2019) and Koenigkam-Santos et al. (2019) consolidated the conceptual foundation necessary to understand the technical, clinical and dimensions The organizational structure of AI applied to radiology. It became evident that this technology does not operate not in isolation, but it integrates into a broader ecosystem of transformation. diagnostic medicine, which includes the exponential growth in the volume of tests, The need for subspecialization, the search for quantitative prognostic markers and The aspiration for truly personalized and precision medicine.

In conclusion, AI is an indispensable ally for the contemporary radiologist, capable of expanding their diagnostic capacity and reducing errors due to fatigue and excessive volume of work. tests, identify early disease patterns, and contribute to the personalization of Caution. However, its implementation must be conducted with scientific rigor. methodological transparency, robust ethical safeguards and ongoing training of professionals. Multicenter, prospective studies with validation are still needed. external to ensure that the performance gains observed under conditions

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experimental studies translate into real and equitable benefits for patients in practice.

everyday clinical practice.

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