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ARTIFICIAL INTELLIGENCE IN RADIOLOGY: COMPREHENSIVE REVIEW OF AUTOMATED MRI AND CT IMAGE ANALYSIS

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Abstract: Artificial intelligence (AI) has emerged as a transformative force in radiology, enabling automated MRI and CT interpretation with unprecedented accuracy and efficiency. This comprehensive review expands on the technical principles, deep learning models, clinical applications, workflow integration, and existing limitations associated with AI in radiological imaging. By examining multimodal datasets, segmentation architectures, evaluation strategies, and regulatory perspectives, the article provides a detailed foundation for understanding how AI systems are currently utilized in neuroradiology, thoracic imaging, stroke diagnostics, and cardiovascular imaging. The review emphasizes the need for robust validation, bias mitigation, explainable AI, and integration with PACS/RIS platforms for safe and effective clinical adoption.

Keywords: Artificial intelligence, deep learning, MRI, CT, radiology, automated diagnosis, segmentation, neural networks

Introduction

Modern radiology faces increasing workload pressures due to the widespread availability of MRI and CT scanners, greater demand for precision medicine, and the expansion of imaging indications. As the number of imaging studies grows, so does the complexity and volume of data that radiologists must interpret. Artificial intelligence (AI), supported by advances in computational power and deep learning, offers a solution to address these challenges by augmenting radiologists' capacity for rapid and accurate diagnosis.

Automated AI tools perform tasks that previously required significant time and expertise, such as identifying subtle abnormalities, segmenting organs and lesions, and providing quantitative metrics. This article delivers a detailed exploration of AI technologies and their expanding role within radiology.

Materials and Methods

The review examines peer-reviewed studies published between 2019 and 2025 from PubMed, Scopus, IEEE Xplore, Radiology, Insights into Imaging, and similar journals. Studies were selected based on their relevance to automated MRI/CT interpretation, segmentation accuracy, and workflow evaluation. Keywords included 'MRI AI', 'CT deep learning', 'radiology automation', and 'medical image segmentation'.

This expanded review includes technical analyses of deep learning architectures, performance metrics, preprocessing techniques, clinical evidence from trials, and regulatory perspectives.

Results

1. Technical Foundations of AI in Radiology

AI systems for radiological applications rely on a structured pipeline that ensures accurate extraction of clinically relevant information from imaging data. The major components include preprocessing, architecture design, training strategy, evaluation, and final deployment within clinical environments.

1.1 Data Acquisition and Preprocessing

AI performance heavily depends on the quality of input data. MRI and CT images undergo preprocessing steps such as resampling, intensity normalization (e.g., Z-score normalization for MRI, HU windowing for CT), and noise reduction. Techniques like histogram equalization, bias field correction, and artifact removal help standardize scans.

Segmentation masks are generated manually or semi-automatically by expert radiologists for supervised learning. Data augmentation methods—including rotations, scaling, elastic deformation, and noise addition—help improve the model's ability to generalize.

1.2 Deep Learning Architectures

Common architectures include CNNs for feature extraction, 3D CNNs for volumetric understanding, and U-Net variants for segmentation. Transformers such as ViT and Swin Transformer have recently been integrated into radiology for their superior global context capture.

Hybrid models combining CNNs and transformers are increasingly used in multimodal imaging tasks requiring spatial and contextual awareness, such as brain tumor classification from MRI.

1.3 Diagnostic Tasks

AI performs classification, detection, segmentation, and quantitative measurement. Classification involves assigning labels to whole images or volumes. Detection localizes abnormalities using bounding boxes or heat maps. Segmentation identifies precise anatomical or pathological regions, and quantitative tasks estimate metrics such as lesion volume, perfusion parameters, or ventricular ejection fraction.

1.4 Evaluation Metrics

Standard evaluation metrics include sensitivity, specificity, AUC for classification; Dice coefficient and IoU for segmentation; and mAP for detection tasks. AI model performance typically exceeds that of traditional CAD systems.

2. Clinical Applications

2.1 Chest CT

Automated AI tools excel in detecting pulmonary nodules, pneumonia, interstitial lung disease, and pulmonary embolism. AI-driven PE detection systems highlight emboli in real-time and alert clinicians, assisting rapid diagnosis and triage. Advanced models quantify severity based on lesion burden, providing essential data for treatment decisions.

2.2 Brain MRI and CT

AI models accurately detect gliomas, meningiomas, and metastatic lesions. They also classify tumors by grade and predict genetic markers such as IDH mutation using MRI alone. For stroke imaging, AI identifies ischemic core regions, hemorrhages, and large-vessel occlusions, significantly reducing treatment delays.

2.3 Cardiovascular CT and MRI

AI supports automated coronary calcium scoring, segmentation of ventricular structures, and detection of ischemic regions. It also measures RV/LV ratios on CT angiography for pulmonary embolism management.

2.4 Enhancing Image Quality

AI-based reconstruction reduces CT radiation dose by denoising and improves MRI resolution while shortening scan times. Deep learning reconstruction surpasses traditional compressed sensing in producing clearer images.

Discussion

AI significantly enhances radiological workflows by improving diagnostic accuracy and accelerating image interpretation. However, challenges remain, including limited generalizability across scanners and institutions, potential bias, and limited explainability. Radiologists are essential for validating AI-generated results, particularly in complex clinical scenarios.

Explainable AI techniques such as Grad-CAM heatmaps help radiologists understand model decisions but require further improvement for clinical reliability. Ethical considerations and regulatory compliance also impact AI deployment.

Conclusion

AI is revolutionizing radiology by providing automated tools capable of segmenting, detecting, and analyzing MRI and CT images with high accuracy. As AI technologies continue to evolve, they will play a central role in future radiological workflows, improving diagnostic precision and patient care. Human oversight remains essential to ensure safety, fairness, and clinical validity.

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