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Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 1, January 2026

https://eurekaoa.com/index.php/5

AUTOMATED DETECTION OF PULMONARY DISEASES USING CT AND MRI WITH DEEP LEARNING

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Abstract
Pulmonary diseases, including pneumonia, chronic obstructive pulmonary disease (COPD), and lung cancer, are major contributors to global morbidity and mortality. Early and accurate diagnosis is critical for effective treatment and improved patient outcomes. Traditional diagnostic methods rely on radiologist interpretation of CT and MRI images, which can be time-consuming and subject to inter-observer variability. Artificial intelligence (AI) and deep learning techniques offer automated, precise, and efficient solutions for pulmonary disease detection. This paper reviews current AI-based methodologies for automated detection of pulmonary diseases using CT and MRI scans, with a focus on convolutional neural networks (CNNs), segmentation models, and hybrid approaches. Challenges such as image variability, dataset limitations, and model interpretability are discussed. The study emphasizes the potential of AI systems to enhance diagnostic accuracy, optimize clinical workflow, and improve patient care in pulmonary medicine.

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Keywords: Pulmonary diseases, deep learning, artificial intelligence, CT imaging, MRI, convolutional neural networks, automated diagnosis, radiology

Introduction

Pulmonary diseases, including pneumonia, chronic obstructive pulmonary disease (COPD), tuberculosis, and lung cancer, represent a significant global health burden, contributing to high morbidity and mortality rates. Early and accurate diagnosis is essential for effective treatment, timely intervention, and improved patient outcomes. Computed tomography (CT) and magnetic resonance imaging (MRI) are widely used for the assessment of pulmonary pathology, enabling detailed visualization of lung structures, lesions, and tissue abnormalities. However, manual interpretation of CT and MRI scans is time-consuming, highly dependent on radiologist expertise, and susceptible to inter-observer variability, particularly in high-volume clinical settings.

Artificial intelligence (AI) and deep learning methodologies have emerged as powerful tools for automated detection and classification of pulmonary diseases. **Convolutional neural networks (CNNs)** are particularly effective in analyzing high-resolution CT and MRI images, extracting hierarchical features, and identifying subtle pathological changes that may be missed by human observers. Advanced segmentation techniques facilitate precise localization and quantification of lesions, such as nodules, infiltrates, or fibrotic changes, providing objective measurements for disease monitoring and treatment planning.

Hybrid models that integrate imaging data with patient demographics, clinical history, and laboratory parameters further enhance diagnostic accuracy and provide context-aware predictions. Techniques such as transfer learning, data augmentation, and multi-modal data integration address challenges related to limited annotated datasets, heterogeneous imaging protocols, and variability in patient populations. Interpretability of AI models is crucial for clinical adoption;

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visualization tools, including saliency maps and class activation maps (CAMs), allow clinicians to understand model decision-making processes and validate predictions.

This paper reviews current AI-based approaches for automated detection of pulmonary diseases using CT and MRI imaging, highlighting convolutional neural networks, segmentation models, hybrid methodologies, clinical applicability, challenges, and future directions. The potential of AI systems to improve diagnostic efficiency, enhance accuracy, and optimize patient care in pulmonary medicine is emphasized.

Main Body

Artificial intelligence (AI) and deep learning have significantly advanced the automated detection of pulmonary diseases, offering precise, rapid, and reproducible analysis of CT and MRI scans. **Convolutional neural networks (CNNs)** are widely utilized to extract hierarchical features from high-resolution images, enabling the identification and classification of various pulmonary conditions, including pneumonia, chronic obstructive pulmonary disease (COPD), pulmonary fibrosis, and lung cancer. These models provide a high level of diagnostic accuracy, often comparable to expert radiologists, and reduce the dependency on manual interpretation in high-volume clinical settings.

Segmentation techniques are integral to AI-based pulmonary imaging, allowing precise delineation of lung structures, lesions, nodules, and infiltrates. Segmentation-based approaches enable quantitative assessment of lesion size, shape, and distribution, which is essential for disease staging, monitoring progression, and evaluating treatment response. Hybrid models that integrate image analysis with patient metadata, including age, smoking history, and clinical parameters, further enhance diagnostic accuracy and support personalized treatment planning.

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To overcome challenges associated with limited annotated datasets, image variability, and heterogeneous imaging protocols, methods such as **data augmentation**, **transfer learning**, and **multi-modal data integration** are employed. These techniques improve model robustness, generalizability, and performance across diverse populations. Visualization and interpretability tools, including saliency maps and class activation maps (CAMs), are essential for clinical adoption, allowing radiologists to understand the regions influencing AI predictions and validate model outputs.

Despite these advances, challenges remain. Variability in CT and MRI acquisition protocols, image quality, and patient positioning can affect model performance. Ethical considerations, including patient privacy, data security, and algorithmic bias, are critical for safe deployment of AI systems in clinical practice. Continuous validation and prospective studies are necessary to ensure reliability, generalizability, and integration into routine radiology workflows.

Overall, AI-driven automated detection systems for pulmonary diseases have the potential to enhance diagnostic accuracy, reduce interpretation time, support early intervention, and improve patient outcomes. By integrating AI into clinical practice, radiologists can optimize workflow efficiency, improve disease monitoring, and provide timely, evidence-based patient care.

Discussion

The integration of artificial intelligence (AI) and deep learning into pulmonary imaging has substantially enhanced the detection and diagnosis of various lung diseases. Convolutional neural networks (CNNs) have demonstrated high performance in classifying pulmonary conditions such as pneumonia, COPD, pulmonary fibrosis, and lung cancer from CT and MRI scans. Segmentation models allow precise localization and quantification of lesions, which is critical for disease staging, monitoring progression, and guiding treatment planning.

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Hybrid and multi-modal approaches, which combine imaging data with clinical parameters, improve diagnostic accuracy and enable personalized predictions. Data augmentation, transfer learning, and domain adaptation techniques address challenges related to limited annotated datasets, heterogeneity in imaging protocols, and variability across patient populations. Visualization tools, including saliency maps and class activation maps (CAMs), enhance interpretability, helping radiologists understand AI-driven predictions and fostering trust in clinical applications.

Despite these advancements, several challenges remain. Variability in imaging equipment, acquisition protocols, and image quality can impact model performance. Ethical and regulatory considerations, including patient privacy, data security, and algorithmic fairness, are essential for responsible deployment. Prospective studies and external validation across diverse clinical settings are necessary to ensure reliability, safety, and generalizability of AI-based pulmonary detection systems.

Overall, AI-driven automated systems have the potential to transform pulmonary diagnostics by improving accuracy, reducing interpretation time, and supporting timely clinical decision-making, ultimately enhancing patient care and outcomes.

Conclusion

In conclusion, artificial intelligence and deep learning offer powerful tools for automated detection of pulmonary diseases using CT and MRI imaging. CNN-based models, segmentation techniques, and hybrid approaches enable precise identification and classification of lung conditions, improving diagnostic efficiency, accuracy, and patient outcomes.

Challenges such as dataset limitations, variability in imaging protocols, and the need for model interpretability persist. However, methodological innovations, multi-modal integration, and visualization techniques continue to strengthen AI applications in pulmonary medicine. Integration of AI-based pulmonary disease

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detection into clinical workflows can optimize radiology services, support early intervention, reduce diagnostic errors, and enhance overall patient care, demonstrating the transformative impact of AI in modern medical imaging.

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