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Application of artificial intelligence in cancer imaging diagnosis: A review

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Abstract. Medical imaging analysis is integral to modern clinical practice, providing crucial insights into internal anatomical structures essential for disease diagnosis and treatment planning. Traditional diagnostic methods often rely on subjective interpretation, leading to inconsistencies and delays. In recent years, artificial intelligence (AI) has revolutionized medical imaging by enhancing diagnostic accuracy and efficiency. AI technologies, particularly deep learning algorithms, process vast datasets to uncover patterns and anomalies, improving lesion detection and classification. This review explores the application of AI on cancer imaging diagnosis, highlighting advancements in image analysis, including lesion detection, segmentation, and feature extraction. It examines the integration of AI with omics technologies for comprehensive patient profiling and personalized treatment strategies. Moreover, the review discusses future directions and ethical considerations, underscoring AI's potential to reshape cancer diagnosis and improve patient outcomes.

Keywords: Artificial intelligence, Cancer, Image diagnosis.

1. Introduction

Medical imaging analysis plays a pivotal role in clinical diagnosis and treatment by providing detailed insights into the body's internal structures, essential for accurately identifying diseases. Traditional diagnostic approaches often rely on expertise and professional judgment from doctors, utilizing symptom observation, clinical signs, and lab results. However, the subjectivity inherent in this method can lead to inconsistencies and inaccuracies due to personal bias and varying experiences. Moreover, manually analyzing medical records and test findings is time-intensive, potentially causing delays in diagnosis, especially when handling a large volume of cases.

In recent years, the integration of artificial intelligence (AI) into medical image analysis has significantly improved lesion detection and diagnostic accuracy [1, 2, 3]. Innovations such as image enhancement and multimodal image fusion have further elevated medical imaging, providing comprehensive and precise diagnostic information. AI technology leverages machine learning and deep learning algorithms to process medical data, offering more precise diagnoses. By analyzing extensive datasets, AI can uncover patterns and trends, enhancing diagnostic accuracy and efficiency. With its automation capabilities, AI can swiftly interpret medical images and test results, reducing the workload on doctors and boosting productivity. AI technologies, particularly deep learning, offer powerful tools for efficiently managing and interpreting large quantities of imaging data [4, 5, 6]. They enhance diagnostic precision and speed, reduce human error, and enable the early detection of conditions such as cancer, which is crucial for improving patient outcomes and survival rates.

In cancer imaging, AI systems analyze image data to detect anomalies, classify different tumor types, and predict disease progression. Deep learning employs neural networks that mimic the structure and function of the human brain, making them particularly adept at processing high-dimensional data such as detailed tumor images. Through tasks like image segmentation, lesion detection, and feature extraction, AI accurately identifies cancerous regions, aiding doctors in making informed decisions [7, 8, 9]. The application of AI in cancer imaging diagnosis has been extensively studied. Bi reviewed the current state of AI in medical imaging for cancer, describing advancements in lung, brain, breast, and prostate tumors to illustrate how common clinical challenges are being addressed [10]. Sadoughi examined various AI techniques utilizing medical images for breast cancer detection [11]. Hunter discussed how AI algorithms assist clinicians in screening asymptomatic patients at risk of cancer, investigating and triaging symptomatic patients, and more effectively diagnosing cancer recurrence [12]. Barragán-Montero presented the foundational technological pillars of AI and state-of-the-art machine learning methods, discussing new trends and future research directions in medical imaging [13]. Koh outlined relevant AI and machine learning techniques, highlighting key opportunities for implementing these technologies in cancer imaging [14]. Their research demonstrates the diverse applications of AI in cancer imaging diagnosis, exploring how AI can improve the accuracy, efficiency, and clinical practice of cancer diagnosis, and firmly confirms the potential for further application and development of AI technology in this field.

This review explores the intersection of artificial intelligence technology and cancer imaging diagnosis, aiming to comprehensively outline the current progress, challenges, solutions, and future directions in this domain. By analyzing existing research findings and clinical practices, the review seeks to offer theoretical and practical support for furthering the application of AI technology in cancer imaging diagnosis. Ultimately, the goal is to advance the detection and treatment of early-stage cancer, thereby enhancing survival rates and the quality of life for patients.

2. Literature Survey

Figure 1 illustrates the annual number of papers retrieved using the search terms “Artificial Intelligence” and “Cancer Imaging Diagnosis” on Google Scholar. The overall trend of relevant literature has been on the rise from 2010 to 2023. The number of papers rose from 10200 in 2010 to a peak of 56400 in 2022. It should be noted that although the number of papers in 2023 is slightly lower than that in 2022, the difference is almost the same. This trend indicates a growing interest in the application of Artificial Intelligence in Cancer Imaging Diagnosis.

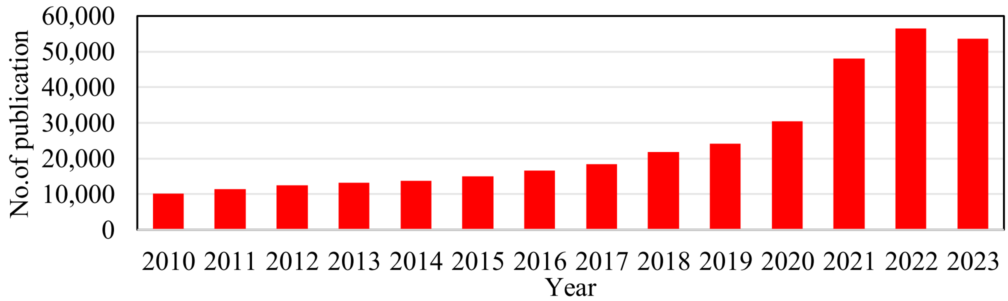

Figure 1. The number of papers searched using “Artificial Intelligence” and “Cancer Imaging Diagnosis” per year

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3. Advanced Applications of AI in Medical Imaging for Cancer Diagnosis

3.1. Medical image analysis and omics

AI technology plays a pivotal role in analyzing diverse medical images such as X-rays, CT scans, and MRIs for early cancer detection, lesion analysis, classification, and treatment monitoring. Integration with omics technology enables rapid analysis of comprehensive patient data, facilitating precise diagnoses and tailored treatment plans. Tumors can be categorized based on characteristics like size and spread, providing crucial insights for clinical decision-making. AI-powered techniques in cancer imaging accurately assess tumor size, shape, texture, and dynamics [15, 16].

Zheng explored AI-driven imaging techniques including mammography, ultrasound, MRI, and PET for breast cancer screening and diagnosis [17]. Telecan discussed advanced decision support tools utilizing texture analysis and AI for MRI image analysis, aiding in prostate cancer diagnosis, staging, aggressiveness prediction, and biopsy guidance [18]. Dynamic contrast uptake assessment in MRI facilitates the characterization of tumor masses by heterogeneity, spatial phenotype, and dynamic features. Systems biology algorithms, combining AI with omics technology, expedite and enhance the accuracy of patient data analysis, supporting precise diagnoses and tailored treatment plans.

3.2. Computer auxiliary diagnosis system

Computer-Aided Diagnosis (CAD) systems are indispensable tools for radiologists in cancer imaging, offering functions such as automatic lesion detection and diagnostic decision support through AI technology. This technological advancement facilitates early cancer detection, reduces the risk of missed or incorrect diagnoses, and advances medical imaging towards intelligent and precise diagnostics [19, 20].

Yao addressed limitations of traditional AI models in breast cancer diagnosis through machine learning, enhancing early detection accuracy and reducing misdiagnosis rates by providing clear medical images and computer-aided diagnosis [21]. Arun and Sasikala focused on deep learning techniques to improve breast cancer detection, exploring architectures like CNN, transfer learning, cross-modal learning, and fine-tuning CNN [22]. Optimization of hyperparameters and effective feature selection strategies can enhance the performance of CAD systems.

3.3. Image segmentation and feature extraction

Deep learning algorithms are instrumental in automating tumor image segmentation and feature extraction, thereby enhancing diagnostic accuracy for healthcare providers. These algorithms efficiently identify patterns and features in medical images, enabling clearer observation of tumor morphology, size, and texture, critical for precise diagnosis and treatment [23, 24].

Tang compared various methodologies for AI nodule segmentation, feature extraction, and classification, including determining optimal deep learning segmentation techniques for lung nodules, employing the Image Biomarker Standardization Initiative (IBSI) for feature extraction, and utilizing principal component analysis (PCA) alongside different machine learning techniques to identify optimal methodologies based on extracted features [25]. Ranjbarzadeh reviewed AI applications in brain tumor segmentation, demonstrating proficiency in distinguishing between abnormal and normal brain tissue [26]. These technologies showcase precision and utility in healthcare settings, particularly in enhancing diagnostic workflows.

4. Future Directions

AI technology is advancing cancer diagnosis by integrating with fields like genomics and molecular diagnostics, expanding its role in medical imaging for precise identification, classification, and personalized treatment planning across various cancer types. This integration incorporates genomic data to enhance understanding of patient genetic profiles, assess risks, and customize treatment strategies. By combining biomarkers and molecular signals with imaging technology, AI improves accuracy in cancer classification, grading, and prognosis. This holistic approach revolutionizes cancer imaging diagnosis, providing precise tools for personalized care and advancing medical diagnostics. Looking forward, AI promises continued advancements in diagnostic precision and efficiency, poised to transform healthcare with enhanced image data mining and analysis capabilities. While offering substantial benefits, the adoption of AI raises ethical considerations such as safeguarding patient privacy, ensuring transparency and interpretability in AI decision-making, and addressing potential biases. It is essential to provide comprehensive ethical training to healthcare professionals and technicians to guide the responsible integration of AI in medical imaging, ensuring adherence to ethical standards and maximizing benefits for patients and society.

5. Summary

Medical imaging analysis is crucial for clinical diagnosis and treatment, offering detailed insights into internal bodily structures essential for identifying diseases accurately. Traditional diagnostic methods rely heavily on clinical expertise and subjective judgment, leading to potential inconsistencies and delays. In recent years, AI has revolutionized medical imaging by enhancing lesion detection and diagnostic precision. AI technologies, particularly deep learning, analyze extensive datasets to uncover patterns, improving efficiency and reducing errors. In cancer imaging, AI aids in anomaly detection, tumor classification, and disease progression prediction, significantly advancing early diagnosis and treatment efficacy. Integrating AI with omics technologies further enhances diagnostic capabilities, offering tailored treatment plans based on comprehensive patient data. As AI continues to evolve, it promises to transform cancer imaging by refining diagnostic accuracy and personalized care, revolutionizing healthcare outcomes.

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