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AI IN ONCOLOGY - DIFFERENTIATING BETWEEN BENIGN MASSES AND MALIGNANT TUMORS IN THE CASE OF BREAST CANCER

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ABSTRACT

Introduction: Cancer poses a considerable challenge to worldwide healthcare systems. Presently, researchers globally are striving to enhance diagnostics and early diagnosis of the disease, which may decrease mortality rates among cancer patients and influence life expectancy. The application of artificial intelligence in medicine, especially in cancer diagnosis, signifies a substantial development. Radiomics plays a crucial role in this field, as it is utilized to augment the effectiveness of image processing for precise early breast cancer diagnosis and to boost overall treatment outcomes.
Aim of the study: The main aim of this work is to clarify the essential ideas related to artificial intelligence, such as machine learning, deep learning, and radiomics, in a comprehensible way. Another aspect was to illustrate the great potential of employing this technology in cancer diagnostics, especially for breast cancer.
Materials and methods: A review of the literature available in the PubMed database was performed, using the key words: „artificial intelligence", „machine learning" ; „deep learning", „radiomics", „breast cancer", „cancer", „oncology".
Conclusion: Artificial intelligence is prevalent in various domains, particularly in medicine, with a focus on oncological diagnosis. Its application can facilitate early disease detection and prompt treatment. Artificial intelligence possesses several limits, presenting a significant challenge for researchers in this domain. Further research on the advancement and enhancement of artificial intelligence methodologies is essential.

KEYWORDS

Artificial Intelligence, Machine Learning, Deep Learning, Radiomics, Breast Cancer, Oncology

CITATION

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Introduction

Artificial intelligence (AI) is a branch of computer science that aims to simulate human cognition, learning, problem-solving, and decision-making. It has begun to play an important role in every aspect of human life, including medicine. AI helps to improve patient care by speeding up processes and increasing accuracy. It also assists in the process of diagnosis and treatment and augments doctors' abilities (Parasher et al., 2020).

Artificial intelligence (AI) is a wide term that includes deep learning (DL) and machine learning (ML). The phrases AI, machine learning, and deep learning are sometimes used synonymously. However, machine learning is a subfield of AI and deep learning is the subset of machine learning (Bhinder et al., 2021). Machine learning applies mathematical algorithms to recognize patterns and correlations within existing training data to cluster new data samples. Deep learning focuses on artificial neural networks with hidden layers that compute a transformation of the underlying data that result in an output layer related with a class (Tran et al., 2019) (Wang & Summers, 2012). Machine learning and deep learning are designed to become essential components of our daily practice, particularly in oncology. The research includes accurate computer-aided diagnoses, assessing pharmacological effectiveness, predicting treatment response and prognostication (Tran et al., 2019). Machine learning and algorithms are utilized in diagnostics, while advanced robotics and medical devices are employed to provide patient care and conduct complex surgeries (Majumder & Sen, 2021). The use of artificial intelligence in cancer diagnosis helps to serve larger populations, eliminate the risk of human error, reduce costs and shorten time.

This article aims to show a vast overview of AI in cancer diagnostics and the challenges that AI faces in the field of oncology. However, it is not exhaustive in scope or detail.

How AI Works?

Artificial intelligence involves giving machines cognitive abilities. It applies computational networks (neural networks) that mimic human nervous systems. Artificial Intelligence originated as a basic set of "if, then rules". It developed over many years to include increasingly complex algorithms. A traditional algorithm consists of rigid, pre-programmed instructions that are executed every time the computer encounters a trigger. Artificial intelligence can modify and create new algorithms in response to learned input without human intervention (Majumder & Sen, 2021).

Machine learning is a technique that utilizes distinct characteristics to discern patterns, which may be employed to study a particular situation. Based on the information it receives, the machine "learns" and applies this data if it encounters a similar problem. Instead of using a traditional algorithm, we can be guided by this dynamic prediction tool in our decision-making process to individualize patient care. Machine learning has evolved into what is currently referred to as deep learning, which consists of algorithms designed to construct artificial neural networks (ANNs) capable of autonomous learning and decision-making, akin to the human brain.

In contrast to static algorithms that evaluate data linearly, the hierarchical functioning of Deep Learning enables computers to process unstructured data non-linearly without human intervention. Each layer transmits data to the layer underneath and relays the output to the layer above, continuing this process sequentially. Similar to the human brain, the machine possesses the capability to autonomously recognize patterns, self-correct, and make informed judgments. Computer vision is the methodology by which a computer acquires information and comprehension from a sequence of images or movies.

The State of Knowledge - AI in Oncology

Over the last 50 years, artificial intelligence has advanced significantly in the medical fields. Thanks to the development of ML and DL, it is possible to create personalized medicine, not just one based on algorithms. The methods of AI can be applied for diagnosis of diseases, prediction of therapeutic response, and potentially preventative medicine one day. Predictive models can improve diagnostic accuracy, improve physician efficiency and clinical operations, facilitate better disease and treatment monitoring, and enhance procedural precision and overall patient outcomes (Stanicki et al., 2021).

World statistics indicate that approximately one in five people develop cancer during their lifetime, whereas one in nine men and one in twelve women die from it (Bray et al., 2024). Early diagnosis and timely intervention might have averted several fatalities. However, diagnosing the early or pre-cancerous disease is a serious challenge. Limiting our activities to standard imaging methods, biomarkers analysis and genetic testing might result in a delay of diagnosis and, consequently, high mortality among cancer patients.

Integrating artificial intelligence techniques in cancer diagnostics allows for reliable tests to be performed on a larger number of patients with fewer qualified personnel, will eliminate the possibility of human error, ensure greater safety, reduce costs and shorten the diagnosis time.

Radiomics

The term "radiomics" was first introduced in 2011. Radiomics involves the extraction of many image characteristics from radiation images using a high-throughput methodology, and the analysis of high-dimensional imaging biomarkers for predictive and prognostic modeling (Gillies et al., 2016) (Lambin et al., 2012) (Tang, 2020). AI's task is to extract mathematical information from digital images, treating them as number patterns. These systems significantly improve the accuracy of image detection for cancer by removing human subjective biases which may ensue from lack of adequate experience, training, or due to time constraints.

Radiomics is a multi-stage process that includes: image acquisition and pre-processing, segmentation (determining the area of interest), feature extraction and selection, and analysis and modeling (Lambin et al., 2012).

Radiomics analysis begins with collecting medical images with quantitative data and preprocessing using standard protocols (e.g. USG, MRI, PET/CT). Original images are enhanced using noise and artifact reduction techniques.

Segmentation, in turn, is the process of designating the anatomical area that will be the subject of image analysis (ROI - regions of interests). Precisely defining the tumor area proved to be a major challenge.

In cancer diagnostics at this stage, many difficulties are encountered due to numerous morphological variations of the tumor, its margins are often blurred as a result of the partial volume effect, and the intensity can be the same as in the case of non-cancerous tissue. The search for ways to deal with such problems is the domain of many AI researchers.

The subsequent phase involves feature extraction. This is the process by which image processing provides potential parameters, features or biomarkers for classification. Feature extraction is considered a key step in radiomics. We analyze alterations in the form, intensity, and texture of the region defined throughout the segmentation process. These activities also serve us to predict the level of differentiation of cancer tissue, and in the next step, they will allow us to assess the potential response to treatment.

The last part of radiomic workflow includes three major procedures: feature selection, modeling, and model validation. A large amount of generated data contains many unnecessary features. At this stage, the task is to keep only the most relevant data of the prediction model and prevent overfitting. Consequently, data must be meticulously chosen to construct a robust statistical model. Feature selection is a technique employed in radiomics that utilizes different methodologies, including filter, wrapper, embedding, and their hybrid combinations (Liu et al., 2019). Then, statistical analysis of the selected, the most relevant data is performed to construct a predictive model for possible clinical outcomes. Modeling is the fundamental procedure in radiomic analysis (Qi et al., 2024). First of all, we need to assess the stability of the extracted data. The goal of this step is to obtain an independent, external, and prospectively validated model for predicting tumor growth, therapeutic efficacy, and clinical prognosis.

The final step is to validate the radiomics model before clinical use. For internal datasets, it is essential for all models, and for externally derived independent data, it is advisable because by detecting and preventing overfitting, we gain greater confidence in our clinical results (Halligan et al., 2021) .

Radiomics in Breast Cancer - Differentiating Benign Masses From Malignant Tumors

The use of artificial intelligence in oncoimaging has two main goals: cancer screening and making therapeutic decisions and predicting treatment effectiveness.

Breast cancer is among the most prevalent cancers affecting women globally, and it is now the leading cause of death from cancer among women (Bray et al., 2024) (Aggarwal et al., 2021).

Regular screening tests help detect cancerous changes at an early stage of the disease, when it can be treated effectively. Early breast cancer screening with mammography, ultrasound, or magnetic resonance imaging (MRI) can significantly enhance the prognosis for individuals with breast cancer (Iranmakani et al., 2020).

In the diagnosis of malignant breast tumors, radiomics has been employed primarily in two domains: tumor categorization and the prediction of the response to therapy and overall clinical outcomes, including survival and recurrence.

Tumor classification includes distinguishing benign from malignant lesions, assigning them to specific molecular subtypes and considering other clinicopathological parameters, such as sentinel node status. This assignment will focus on discussing the first topic.

The most commonly used screening test in breast cancer diagnostics, which allows for initial differentiation of the nature of the changes, is mammography. For this reason, the vast majority of radiomic models will be based on mammography. Numerous researchers have concentrated on identifying the most critical areas in the breast where feature extraction will produce the most pertinent information.

Mudigonda et al. examined the efficacy of textural information from mass regions relative to that from mass margins in their study. Malignant tumors display a seemingly wide array of gradient and the gray-level co-occurrence matrix features, particularly around the tumor edge, in contrast to benign nodules. The optimal benign versus malignant classification of 82.1% was achieved utilizing images from the Mammographic Image Analysis Society database (Desautels et al., 2000).

Li et al. indicated that integrating the attributes of normal parenchyma from the contralateral breast with radiomic properties of breast cancers could enhance the diagnostic accuracy of digital mammography for breast cancer (Li et al., 2019).

In recent years, research has been conducted on building of radiomic models for the classification of tumors, the images of which were obtained using advanced technologies such as contrast-enhanced mammography (CEM). The deep learning model precisely recognized and defined suspicious lesions on contrast-enhanced mammography images, whereas the integrated output of the deep learning and handcrafted radiomics models demonstrated commendable diagnostic efficacy (Beuque et al., 2023).

Interesting research was also conducted by Drukker et al. They invastigated the integration of mammography radiomics and quantitative three-compartment breast (3CB) image processing from dual-energy mammography to reduce unneeded breast biopsies of benign masses. In conclusion, the integrated model may decrease total biopsies by 35.8% vs to standard mammography (Drukker et al., 2019).

As mentioned earlier, MRI is also used as a screening test for breast cancer, especially in the diagnosis of suspicious changes in mammography defined as BIRADS 4a or 4b (Bickelhaupt et al., 2018) .

Zhang et al. developed an automated computer-aided diagnosis (CAD) pipeline utilizing multiparametric magnetic resonance imaging (mpMRI) and investigated the significance of several imaging parameters in breast cancer classification. The model achieved an area under curve (AUC) of 0.95, and the integration of the radiomics score with the BIRADS score elevated the AUC to 0.98 (Zhang et al., 2023).

In summary, using radiomics to explore features extracted from mammography and MRI can create effective and efficient models to differentiate benign tumors from cancerous ones.

Summary

Artificial intelligence (AI) is a branch of computer science that aims to simulate human cognition, learning, problem-solving, and decision-making. It plays a crucial role in various aspects of human life, including medicine, improving patient care, diagnosis, treatment, and augmenting doctors' abilities. AI, including deep learning and machine learning, is designed to become essential components of daily practice, particularly in oncology. Machine learning uses mathematical algorithms to recognize patterns and correlations within training data, while deep learning focuses on artificial neural networks with hidden layers that compute a transformation of underlying data. AI in cancer diagnosis helps serve larger populations, eliminate human error, reduce costs, and shorten time.

AI has significantly advanced in medical fields, enabling personalized medicine and improved diagnostic accuracy. In cancer diagnostics, AI can enhance patient outcomes by reducing human error, ensuring safety, and reducing costs. Radiomics is a field that extracts image characteristics from radiation images. Radiomics involves image acquisition, pre-processing, segmentation, feature extraction, and analysis.

Research has shown that radiomics can improve diagnostic accuracy in breast cancer screening.

Disclosure

Author's contribution:

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