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Deep Learning and Radiomics Fusion: A Breakthrough in Predicting Pathological Complete Response in Locally Advanced Esophageal Cancer

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Introduction

Esophageal cancer, especially the esophageal squamous cell carcinoma (ESCC) subtype, is a challenging and often life-threatening diagnosis. For patients with locally advanced ESCC, neoadjuvant chemoradiotherapy (nCRT) is a common treatment approach, aiming to improve surgical outcomes. However, predicting the response to this therapy has remained a complex task. A recent two-center study has shed light on a groundbreaking solution: deep learning radiomics analysis of pre- and post-nCRT CT images. This innovative approach not only enhances the prediction of pathological complete response (pCR) but also introduces a novel model combining deep learning, radiomics, and hematological parameters. In this article, we delve into the significant findings and implications of this study.

Description

Pathological complete response (pCR) following neoadjuvant treatment is a critical indicator of treatment success. It signifies the complete disappearance of cancerous cells in the surgical specimen, which often leads to more favorable outcomes. However, accurately predicting which patients will achieve pCR remains a complex challenge, particularly in the context of locally advanced ESCC. The two-center study unveiled a game-changing approach in the form of deep learning radiomics analysis. This methodology involves the extraction and analysis of a vast array of quantitative image features from pre- and post-nCRT CT scans. These features are processed using deep learning algorithms, providing a comprehensive assessment of tumor characteristics and changes over the course of treatment [1].

What makes this study particularly compelling is the revelation that the combined model, incorporating both clinical and radiomics data, outperformed the clinical model and radiomics model individually in predicting pCR for locally advanced ESCC. This integrated approach promises to be a significant advancement, providing a more accurate and comprehensive understanding of treatment response. Within the framework of the combined model, the logistic regression (LR) classifier demonstrated the best performance in the current study. Its ability to analyze and interpret the data effectively played a pivotal role in refining the predictive accuracy [2].

A critical aspect of this study is the evaluation of its clinical utility. Decision curves, a tool for assessing the net benefit of a predictive model, revealed that the novel predictive model based on deep learning, radiomics, and hematological parameters offers great clinical utility. This suggests that the model's predictions are not only accurate but also beneficial for informing clinical decisions. The two-center study's findings mark a significant step forward in the quest to improve outcomes for patients with locally advanced ESCC. The integration of deep learning radiomics, clinical data, and hematological parameters introduces a novel predictive model that promises to enhance the prediction of pCR following neoadjuvant treatment [3].

This innovation holds the potential to guide treatment decisions, ultimately leading to more personalized and effective care for ESCC patients. As research continues, we can anticipate further advancements in the field of oncology, offering hope to those facing the formidable challenge of esophageal cancer. Esophageal carcinoma is a prevalent malignancy globally, ranking seventh in incidence and sixth in cancer-related mortality. Alarmingly, over half of the new cases reported each year are from China, predominantly involving esophageal squamous cell carcinoma (ESCC). Evidence from the CROSS trial underscored the significant benefits of adding neoadjuvant chemoradiotherapy (nCRT) to surgery for locally advanced ESCC patients, showing a remarkable 13% absolute overall survival benefit at 10 years [4].

While the CROSS trial also revealed that a substantial one-third of patients achieved a pathological complete response (pCR) following nCRT, the long-term follow-up disclosed that nearly 39% of patients experienced distant progression. This raises the pivotal question of whether surgery should be reserved exclusively for patients with residual disease post-nCRT and no distant metastasis. Recent studies have explored the potential of nCRT combined with active surveillance for ESCC patients who achieved clinical complete response (cCR). However, given the disease's severe prognosis, accurate assessment of treatment response is imperative before deciding to forgo surgery. Presently, evaluating treatment response in ESCC mainly relies on invasive procedures such as endoscopic biopsy and various imaging assessments including CT, MRI, and PET/CT [5].

The need for invasive procedures poses both physical and psychological burdens on patients, highlighting the pressing need for a noninvasive method to accurately predict treatment response. Radiomics, a methodology that captures intricate imaging features beyond human perception, offers a promising approach. Quantitative radiomics enables the visualization of tumor phenotype distinctions noninvasively, serving as a potential biomarker for predicting treatment response. Deep learning, specifically Convolutional Neural Networks (CNNs), has shown remarkable potential in tasks related to medical imaging, classification, and tumor detection and staging. CNNs are constructed with multiple hidden layers between input and output layers, which can be convolutional, pooling, or fully connected.

Utilizing pretrained CNNs to extract deep learning features has been proven effective in various contexts. Additionally, the combination of deep learning features extracted from CNNs has exhibited excellent performance in predicting treatment response across different cancers. In a study by Hu and colleagues, a model employing a pretrained CNN to extract deep learning features for predicting pCR following nCRT in ESCC demonstrated superior predictive performance (with an AUC of 0.805) compared to models based on handcrafted radiomics features. Nevertheless, the high heterogeneity of tumors and the influence of nCRT may lead to distinct phenotypes at different time points.

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Conclusion

Primary tumor characteristics may manifest in pre-treatment CT images, while response status may be evident in post-treatment CT images. Hence, there's potential value in incorporating both pre- and post-treatment CT data into a radiomics model. To facilitate routine clinical application, integrating meaningful biomarkers into the radiomics model can further enhance predictive accuracy. Emerging evidence has underscored the significant influence of nutrition and inflammation on various cancers' prognosis, including esophageal cancer. Systemic immunoinflammatory response biomarkers such as the neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and lymphocyte-to-monocyte ratio (LMR) have proven useful in predicting malignancy outcomes. Therefore, this study sought to develop deep learning radiomics models based on pre- and post-treatment CT images, incorporating hematological biomarkers. The goal is to assess the likelihood of achieving pCR in ESCC following nCRT, providing valuable clinical insights for active surveillance applications.

Acknowledgement

None.

Conflict of Interest

None.

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