Intelligent Diagnosis and Prediction of Pancreatic Cancer based on Unimodal and Multimodal Data

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Abstract: Pancreatic cancer is a fatal disease, which has become a difficult problem for the medical community due to its high mortality rate and the great challenge of early diagnosis. This review focuses on the frontier of diagnosis and prediction methods of pancreatic cancer in different data modalities, it introduces the pathological basis and clinical difficulties of pancreatic cancer, and then in-depth analyzes two core technical paths: the model based on one-dimensional clinical data, and the medical imaging data model subdivided into unimodal and multimodal imaging analysis. Although the models based on one-dimensional data show practical value in the field of risk stratification and prediction, the method of feature extraction and multimodal information fusion based on image data with the help of deep learning has important potential in improving the accuracy and automation of early diagnosis. This paper analyzes the shortcomings of current methods in data quality, model interpretability and generalization ability, and looks forward to future research directions.

Keywords: Diagnosis; Deep learning; Medical imaging; Multimodal data.

1 Introduction

There is often a lack of specific symptoms in the early stage, and most patients have already entered the advanced stage or have metastasis when diagnosed, which completely misses the golden opportunity for radical surgery. From a macro perspective, with the aging of the population and changes in lifestyle, the incidence of pancreatic cancer continues to rise in many regions, bringing a heavy burden to the medical system [1]. Therefore, improving the early diagnosis rate and prediction accuracy of pancreatic cancer has become the core mission of clinical diagnosis and treatment and academic research.

In addition, pancreatic cancer has high biological heterogeneity and complex molecular regulatory mechanisms. Its occurrence and development are affected by multiple factors such as genetic factors, metabolic status, inflammatory response and tumor microenvironment, and there are often significant differences in disease process and treatment response between different patients. This complexity not only increases the difficulty of accurate disease identification and risk assessment, but also poses a serious challenge to traditional analysis methods based on single modality or limited features [2]. Therefore, how to integrate multi-

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source heterogeneous data to achieve a systematic description of the mechanism and evolution of pancreatic cancer has become a key research direction to promote the development of precision medicine.

In clinical practice, the diagnosis of pancreatic cancer mainly relies on traditional methods such as imaging examination, endoscopic ultrasound and serological marker detection. However, the above methods still have problems such as insufficient sensitivity, limited specificity or high invasiveness in early lesion identification, small lesion detection and individualized risk assessment, which make it difficult to comprehensively describe the complex evolutionary characteristics of the disease. Especially in the context of high heterogeneity, the diagnostic mode based on a single modality of information is difficult to meet the realistic needs of precision diagnosis and treatment. In recent years, the rapid development of artificial intelligence and machine learning technology has provided a new technical path to break through the above bottlenecks. Through the deep mining and collaborative modeling of multi-source clinical data and medical image information, the construction of an efficient and robust intelligent auxiliary diagnosis system has gradually become an important research direction in the field of early screening and risk prediction of pancreatic cancer [3, 4]

In this context, the importance of systematic sorting and objective evaluation of existing technology pathways is self-evident. This article aims to comprehensively review the latest progress of clinical data and medical imaging data-driven diagnosis and prediction models for pancreatic cancer, in-depth analyze the core principles, unique advantages and representative applications of each method, and discuss the current challenges and potential future development trends, so as to provide valuable reference for researchers in related fields.

2 Basic information

The occurrence and development of pancreatic cancer is a complex pathological processes. Smoking, chronic pancreatitis, diabetes, obesity and specific genetic syndromes are all risk factors that promote the occurrence of the disease. Its clinical manifestations are extremely insidious, and common symptoms such as abdominal pain, jaundice, unexplained weight loss and dyspepsia often appear gradually in the advanced stage of the disease [5, 6]. At the pathological level, the pro-fibrotic microenvironment is its typical feature, which not only lays the foundation for the aggressiveness of the disease but also sets up many obstacles for imaging diagnosis and clinical treatment [7].

3 Diagnosis and prediction of pancreatic cancer based on one-dimensional data

Building a prediction model based on one-dimensional structured data such as electronic health records, laboratory test results, and demographic information is computationally efficient and easy to apply in clinical practice. Such models often use classical algorithms such as logistic regression, random forest or support vector machine. Their advantage lies in their ability to integrate a variety of clinical variables to realize disease risk stratification and

prognosis prediction, and provide a simple and practical reference for clinical decision-making. Zhuang Pengjie proposed a variety of intelligent modeling methods around the survival prediction of pancreatic cancer in the environment of electronic health records. Firstly, he proposed feature extraction and Combination based on a large language model (TNMor) for pancreatic cancer staging. By constructing a morphological feature instruction dataset and fine-tuning the large language model, the morphological features of tumors in pathological reports were automatically extracted, and combined with a feature combination mechanism based on survival weight to construct a new staging system. The experimental results show that the proposed method has stronger discriminative power than the traditional TNM staging method in the prognosis prediction task of patients with resected pancreatic ductal adenocarcinoma, and can construct a more accurate survival risk prediction model. Secondly, it proposed a deep Q learning method based on supervised reward enhancement for pancreatic cancer survival prediction (Sr-DQN), which modeled the survival prediction task as a sequential decision process, represented the preoperative features of the patient as a Markov decision environment, and automatically generated the reward function through an external supervised classifier to guide the agent to make feature selection and prediction decisions. At the same time, the action selection strategy combined with the rule constraint is used to balance the prediction accuracy and decision stability. Experimental results show that the proposed method can effectively identify the key features with individualized indicative significance, and outperforms the existing methods in terms of overall prediction performance. Furthermore, he proposed a pancreatic cancer survival prediction method (SPA) based on large language model agents. By constructing multiple LLM agents with complementary functions, and designing corresponding instruction prompts for different prediction steps, the agents were guided to cooperate to complete information summary, risk prediction, result evaluation and interpretation analysis. Thus, potential prognostic factors in electronic health records were mined under zero-sample condition. Experimental results show that this method can achieve high prediction accuracy on real clinical data and has good interpretation and analysis ability [8].

4 Diagnosis and prediction of pancreatic cancer based on imaging data

4.1 Analysis based on unimodal images

Computed tomography (CT) is undoubtedly the first-line imaging tool for the diagnosis of pancreatic cancer. Deep learning methods based on CT images, convolutional neural network is used to automatically mine the deep features such as morphology and texture of tumors, and realize the automatic detection, segmentation and classification of benign and malignant tumors. Xu Lijun et al. proposed a glioma MRI image segmentation method based on 3D-Ghost convolutional neural network (3D-GA-Unet), aiming to improve the accuracy and computational efficiency of glioma segmentation. Based on the 3D U-Net framework, the 3D-Ghost CNN module is introduced to generate effective features through linear operation to reduce redundant information. At the same time, the coordinate attention mechanism is fused to enhance the modeling ability of the network for key spatial information, so as to improve the recognition ability of tumor regions. The experiment was verified on the BraTS2018

public dataset. The results showed that the average Dice similarity coefficient of the proposed method in the surrounding edema region, necrotic core region and enhanced tumor region reached 0.8632, 0.8473 and 0.8036, respectively, and the average sensitivity reached 0.8676, 0.9492 and 0.8315, respectively. The proposed method showed high segmentation accuracy and stability. The research results show that 3D-GA-Unet can achieve accurate segmentation of glioma images and improve the diagnostic auxiliary value while ensuring efficiency, which has positive significance for clinical application [9].

4.2 Analysis based on multimodal images

Multimodal methods that cleverly integrate the complementary information of different imaging techniques or different imaging phases are expected to provide a more comprehensive representation of the tumor, just like a "panoramic detector" for the doctor. Focusing on the application of PET/CT multimodal imaging in the accurate diagnosis of benign and malignant pancreatic lesions, Liu has constructed a variety of intelligent auxiliary diagnosis models. Firstly, he proposed a radiomics diagnostic model based on PET/CT dual-time imaging. Through high- throughput extraction of gray intensity, morphology, texture and clinical experience features, and combined with support vector machine recursive feature elimination method to screen the optimal features, and SVM classifier was used to achieve quantitative differentiation of AIP and PDAC. The experimental results showed that the proposed model had the best diagnostic performance, with an AUC of 0.9668 and an accuracy of 89.91%, which significantly improved the ability to distinguish benign and malignant pancreatic lesions. Secondly, aiming at the low efficiency and poor repeatability of manual segmentation of lesions, an improved PET/ CT-based Faster R-CNN multi- class object detection model was proposed. By optimizing the feature pyramid structure, multimodal attention fusion mechanism and training strategy, the automatic detection and classification of AIP and PDAC lesions were realized. The experimental results show that the proposed model achieves better performance in multimodal detection tasks, with a mAP of 70.56%, which effectively improves the efficiency of clinical diagnosis. Furthermore, in order to reduce the cost and radiation risk of PET/CT examination, a cross-modal image generation method MSCBGAN based on generative adversative network was proposed. On the basis of the pix2pix framework, multi- scale feature fusion and hybrid attention mechanism were introduced to realize the generation of SPET images from CT images. The corresponding radiomics classification model was constructed to verify the results. Experimental results show that this method can generate high-quality SPET images (structural similarity is up to 0.839), and is superior to the single CT modality in the classification task, which verifies the feasibility and effectiveness of generating image-based technology in assisting the diagnosis of pancreatic lesions [10].

5 Existing limitations and future prospects

At present, related research still faces many challenges that need to be solved urgently. The lack of high-quality, large-scale, and finely annotated multicenter data sets seriously limits the generalization ability of models. Most deep learning models are like "black boxes", with a lack of interpretability in the decision-making process, which makes it difficult to win the full trust of clinicians. How to efficiently integrate imaging information with non-imaging data such as genomics and pathology to build a more powerful prediction system has become a key topic

for future research. The future exploration should focus on the development of explainable AI, promote standardized data sharing, and conduct prospective clinical trials to verify the real clinical utility of models, so that the technology can truly serve the clinic.

6 Conclusions

This paper systematically reviews the latest progress of intelligent diagnosis and prediction models for pancreatic cancer driven by one-dimensional clinical data and medical imaging data. The analysis shows that the models based on one-dimensional data have practical value in risk prediction and prognosis evaluation, while the methods based on image data, especially with the help of deep learning and multimodal fusion technology, have made breakthroughs in improving the accuracy and automation level of early diagnosis. Although there are still shortcomings in data quality, model interpretation and generalization ability, the deep integration of artificial intelligence technology and clinical practice has become an irreversible trend of The Times. In the future, through close interdisciplinary cooperation and overcoming the existing bottlenecks, a reliable and efficient intelligent auxiliary diagnosis system that can truly improve the prognosis of patients with pancreatic cancer will be developed.

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