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The Application of Imaging and Molecular Markers in Cancer Diagnosis and Treatment

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Abstract. Cancer is one of the leading causes of death worldwide, and its diagnosis and treatment face many challenges. In recent years, the combination of imaging techniques and molecular markers has made remarkable progress in cancer diagnosis and treatment. Imaging techniques such as CT, MRI and PET-CT can provide anatomical and functional information of tumors, while molecular markers such as EGFR and HER2 play a key role in tumor diagnosis, prognosis and treatment. However, how to effectively combine these technologies to achieve more accurate diagnosis and treatment is still a gap in research. This paper reviews the combined application of imaging technology and molecular markers in cancer diagnosis, therapeutic response monitoring and individualized therapy, analyzes the synergistic effect of multimodal imaging technology and molecular markers, and finds that it has significant advantages in early detection and individualized treatment planning. Combining imaging and molecular marker information can improve the accuracy of cancer diagnosis and guide targeted therapies. The combination of such technologies provides a new reference for precision cancer medicine in the future, but further research is still needed in the aspects of marker sensitivity and image analysis automation. In the future, the combination of new technologies such as artificial intelligence is expected to promote the development of more accurate and efficient cancer diagnosis and treatment.

Keywords: Radiological technology; molecular markers; imaging diagnosis; individualized treatment; multimodal image.

1. Introduction

Cancer is one of the leading causes of death worldwide. According to the World Health Organization, there will be about 19 million new cancer cases worldwide in 2020, and about 10 million deaths [1]. With the aging of the global population and changes in lifestyle, the incidence and mortality of cancer continue to rise [2]. Despite significant advances in cancer treatment, many challenges remain in cancer diagnosis and treatment [3]. The complexity and heterogeneity of cancer make its diagnosis and treatment extremely challenging. Traditional diagnostic methods (such as tissue biopsy and cytology), while effective in some cases, have problems such as trauma, sensitivity and lack of specificity. At the same time, traditional treatments (such as surgery, chemotherapy, and radiation) may not work well in some patients and come with serious side effects. Therefore, the development of more accurate and personalized cancer diagnosis and treatment methods is particularly important. Over the past few decades, scientists have made many important advances in cancer diagnosis and treatment. Imaging techniques and the application of molecular markers are two important areas.

Imaging techniques such as CT, MRI, PET, and PET-CT offer detailed anatomical and functional insights into tumors. For instance, PET-CT integrates the functional data from PET with the anatomical precision of CT, providing comprehensive information on both the metabolic activity and structural characteristics of tumors. This integration significantly enhances the accuracy of tumor detection. Molecular markers, including the epidermal growth factor receptor (EGFR), human epidermal growth factor receptor 2 (HER2), KRAS, and BRCA1/2, are crucial for the diagnosis, prognosis, and treatment of cancer. By detecting these molecular markers, physicians can more accurately predict disease progression, assess treatment effectiveness, and tailor treatment plans.

The importance of the combination of imaging techniques and molecular markers in cancer diagnosis and treatment is reflected in the following aspects. First, cancer can be detected earlier, improving early diagnosis and thus cure rates. For example, PET-CT combined with 18F-FDG can detect the presence of tumors when they are small and have not yet produced obvious symptoms. In addition, the technology can provide more comprehensive and accurate tumor information, improving the accuracy and reliability of diagnosis. By combining imaging and molecular markers, doctors can develop more precise, individualized treatment plans, select appropriate targeted therapeutic drugs, and monitor treatment effects in real time. Detection of EGFR mutations, for example, can guide the use of EGFR inhibitors in patients with non-small cell lung cancer (NSCLC), while imaging can monitor tumor response to treatment. Evaluation of treatment effect and monitoring of disease progression: The combination of imaging techniques and molecular markers can dynamically monitor the patient's treatment response and disease progression, helping doctors to adjust treatment regimen in time and improve treatment effectiveness. For example, 18F-FDG PET/CT can be employed to monitor the treatment response of lymphoma patients and help doctors determine whether treatment needs to be adjusted. The combination of imaging techniques and molecular markers has important clinical significance and research value in cancer diagnosis and treatment. With the continuous advancement of technology, the research and application in this field will further promote the precision and individualized development of cancer diagnosis and treatment, bringing better prognosis and quality of life to patients.

This paper aims to explore the application potential of multimodal imaging technology in different cancer species through in-depth analysis of the synergistic effect of multimodal imaging technology and molecular markers, in order to provide an important reference for the future research of precision cancer medicine. The results of the study showed that the combination of imaging technology and molecular marker information could not only improve the accuracy of diagnosis, but also optimize the formulation of individualized treatment plans, and provide theoretical support for improving the treatment effect and prognosis of patients.

2. Applications

2.1. In Cancer Diagnosis and Treatment

2.1.1. The importance of imaging techniques in cancer diagnosis

T Imaging techniques are important tools in cancer diagnosis, of which PET-CT (a combination of positron emission tomography and computed tomography) is a highly effective imaging technique.

2.1.2. Applications of PET-CT in cancer diagnosis and treatment

PET-CT integrates the functional insights of PET with the anatomical details of CT, offering comprehensive information on both the metabolic activity and structural characteristics of tumors. In PET-CT, 18F-FDG (fluorodeoxyglucose) is the most commonly used radiotracer. 18F-FDG, a glucose analogue, serves as a marker for glucose metabolism in tissues. Given the elevated metabolic rates characteristic of most tumor cells, 18F-FDG PET-CT is highly effective in identifying and localizing tumors. [4].

18F-FDG PET-CT has important applications in the diagnosis and monitoring of various cancers. For instance, in the diagnosis of lung cancer, 18F-FDG PET-CT is employed to differentiate between benign and malignant lung nodules, ascertain tumor staging, and evaluate treatment efficacy. Furthermore, 18F-FDG PET-CT is extensively utilized in the diagnosis and monitoring of various malignancies, including breast cancer (BC), colorectal cancer (CRC), and lymphoma.

2.1.3. Classification of molecular markers and their role in cancer

A notable example is the use of 18F-FDG PET-CT to assess treatment response in patients with lymphoma. Research has demonstrated that the level of 18F-FDG uptake following treatment serves as a reliable indicator for evaluating the therapeutic efficacy in lymphoma." [5], which can help

doctors determine whether patients need to adjust the treatment plan. In addition, 18F-FDG PET-CT can also be used for preoperative evaluation to help surgeons develop a more precise surgical plan and improve the success rate of surgery.

2.2. The Multimodal Imaging Techniques with Molecular Markers

2.2.1. Advantages

Molecular markers are specific molecules that can be detected in tissues, cells, or body fluids by biochemical assays [6]. Molecular markers can be classified according to their functions and application scenarios, mainly including the following categories. Diagnostic markers are used for the early detection and diagnosis of diseases. For example, prostate-specific antigen (PSA) is used to screen for prostate cancer. Prognostic markers are used to predict disease progression and patient prognosis. For example, Ki-67 is a marker used to evaluate the proliferative activity of BC. Predictive markers are used to predict a patient's response to a particular treatment. For example, EGFR mutation status can be used to predict the response of NSCLC patients to EGFR inhibitors.

2.2.2. Prospects of multimodal imaging techniques like PET/MRI

EGFR is a transmembrane protein whose mutations are closely associated with the development and development of a variety of cancers, such as NSCLC, CRC, and head and neck cancers. Detection of EGFR mutations can help select suitable targeted therapies. HER2 is commonly overexpressed in BC and gastric cancer. Her2-positive patients may benefit from HER2-targeted treatments such as trastuzumab. Mutations in the KRAS gene are frequently observed in colorectal cancer (CRC) and pancreatic cancer. The detection of KRAS mutation status can be valuable for guiding the selection of targeted therapy. Additionally, mutations in the BRCA1/2 genes are closely linked to a heightened risk of breast cancer (BC) and ovarian cancer. [7], and detection of these gene mutations helps in early screening and prevention.

2.2.3. Role of imaging and molecular markers in personalized therapy

The application of multimodal imaging technology combined with molecular markers has significant advantages in cancer diagnosis [8]. Multimodal imaging technology integrates various imaging modalities, including PET, CT, and MRI, to offer more comprehensive and precise diagnostic information. This approach enhances the sensitivity and specificity of tumor detection, providing clinicians with enhanced tools for accurate diagnosis and treatment planning.

68Ga-FAPI (68GA-sialylation peptide) is a novel radiotracer capable of targeting fibroblast activating protein (FAP) in tumor stroma [9]. Compared to conventional 18F-FDG, 68Ga-FAPI has greater specificity and sensitivity in detecting certain types of tumors, such as pancreatic cancer and gastrointestinal stromal tumors. 68Ga-FAPI PET/CT has demonstrated promising outcomes in the detection of various types of cancers [10]. For instance, in the diagnosis of pancreatic cancer, 68Ga-FAPI PET/CT is capable of providing clearer visualization of tumor tissue and reducing the interference from inflammatory tissue. In addition, the technology can be used to assess treatment response and monitor disease progression. 68Ga-FAPI PET/CT also shows high specificity in the detection of gastrointestinal stromal tumors, which can accurately distinguish tumor tissue from surrounding normal tissue, thus improving the accuracy of diagnosis.

Multimodal imaging techniques combined with molecular markers can provide more comprehensive tumor information [11]. For example, PET/MRI (a combination of positron emission tomography and magnetic resonance imaging) is an emerging multimodal imaging technology. Compared with PET/CT, PET/MRI can not only provide high-resolution anatomical structure images, but also provide richer soft tissue contrast information, thereby improving the detection and staging of tumors. In addition, multimodal imaging technology can also combine different molecular markers to provide more biological information. For example, 18F-FDG PET/CT can be employed in combination with 18F-FLT (fluorothymidine) PET/CT to simultaneously assess glucose metabolism and proliferative activity in tumors [12]. This multi-modal, multi-marker approach offers a more comprehensive

understanding of tumor biology, enabling doctors to develop more precise and effective treatment plans.

In clinical practice, the combination of imaging and molecular markers has been widely used in the diagnosis, treatment and monitoring of a variety of cancers. For example, in the diagnosis of BC, the combination of MRI with HER2 markers can provide more accurate tumor staging and prognostic information. In the treatment of NSCLC, the combination of PET/CT and EGFR markers can help physicians select appropriate targeted therapeutic agents and monitor the effectiveness of treatment.

2.2.4. Future outlook of the combination of imaging techniques and molecular markers.

The combination of imaging and molecular marker technology plays an important role in the development of individualized treatment regimens. Through comprehensive analysis of imaging and molecular marker information, doctors can more accurately assess patients' conditions and develop personalized treatment plans [13].

In individualized therapy, the combination of imaging and molecular markers can help identify appropriate therapeutic targets and evaluate therapeutic effects [14]. For example, in the treatment of NSCLC, detection of EGFR mutation status can guide the selection of EGFR inhibitors, while imaging can assess tumor response to treatment. In addition, for the treatment of breast cancer (BC), patients with HER2-positive status can benefit from targeted therapies that focus on HER2. Imaging techniques can also be utilized to monitor tumor changes during treatment, thereby helping to evaluate the effectiveness of the therapy.

2.2.5. Therapeutic response monitoring and disease progression assessment

Imaging and molecular markers can also be used to monitor treatment response and assess disease progression. By dynamically monitoring the changes of molecular markers, the therapeutic regimen can be adjusted in time to improve the therapeutic effect. In addition, imaging techniques can visually show the shrinkage or spread of tumors. For example, in the treatment of lymphoma, 18F-FDG PET/CT can be employed to monitor tumor metabolic activity after treatment and help doctors determine whether treatment needs to be adjusted.

3. Conclusion

This article reviews the application of imaging techniques and molecular markers in the diagnosis and treatment of cancer. Firstly, imaging techniques such as CT, MRI, and PET-CT are essential for the early diagnosis of cancer, staging of tumors, and monitoring the response to treatment. Secondly, molecular markers such as EGFR,HER2,KRAS,etc.are essential for accurately diagnosing tumors and formulating individualized treatment plans. By combining imaging techniques with molecular markers, the sensitivity and specificity of cancer diagnosis can be significantly improved, and treatment selection and efficacy evaluation can be effectively guided.

Although some progress has been made in cancer diagnosis and treatment, how to further optimize the integrated application of imaging and molecular markers is still an important direction of future research. With the continuous advancement of technology, especially the introduction of artificial intelligence and more sensitive molecular markers, this field will play a greater role in the early detection of cancer, personalized treatment and prognosis assessment in the future, thus bringing better treatment results to cancer patients.

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