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The Research Progress and Modification Strategy on Curing Cancer: The Multidimensional Analysis Based on Precision Health Care

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Abstract: Cancer is one of the key diseases that pose a significant threat to human health in the world. Due to its increasing prevalence and mortality rates, the need for an innovative curing method is urgent among countries. This paper presents a comprehensive overview of the progress and challenges of conventional cancer treatment and carries out a thorough analysis on the therapeutic mechanism and future development prospects. The paper further proposes improvements in multi-modal combined therapy, personalized real-time monitoring solutions and AI-driven efficacy prediction models. This study concludes that these innovative approaches could significantly enhance the effectiveness of cancer treatment by integrating advanced technologies and personalized strategies. Based on a comprehensive analysis of relevant experimental evidence, the paper reveals the clear trend of cancer treatment shifting from a standardized model to a personalized approach, providing a strong theoretical foundation for the development of an international cancer prevention network and therapeutic system.

Keywords: Cancer treatment, Precision Medicine, Immune Treatment, Multi-modal Combined Therapy, Artificial Intelligence

1. Introduction

Cancer continues to be one of the most pressing and complex challenges in global public health. As reported by the World Health Organization (WHO), in 2020, there were an estimated 19.3 million new cancer cases worldwide, contributing to nearly 10 million deaths. Among these, the impact of solid tumors, such as lung, gastric, and colorectal cancers, is particularly significant, representing a substantial burden on healthcare systems globally. These cancers often present late-stage diagnoses, which complicate treatment and worsen prognoses. While conventional cancer therapies, such as chemotherapy, radiotherapy, and surgery, have been cornerstones in cancer treatment for decades, they face several critical challenges. These include the management of metastatic cancer, where the disease spreads to distant organs, resistance to drugs, and the severe side effects that significantly affect the quality of life for patients. The toxicity of chemotherapeutic agents, for instance, can cause damage to healthy cells, leading to complications like immunosuppression, anemia, and fatigue. However, with the rapid advancements in genomics, immunology, and molecular biology, cancer treatment has entered a new phase known as precision medicine. This approach aims to target specific genetic mutations, molecular pathways, and immune system interactions unique to each patient's

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tumor. Targeted therapies, immune checkpoint inhibitors, and personalized vaccines have shown great promise in improving treatment efficacy and minimizing side effects. The emergence of liquid biopsy techniques, for example, allows for non-invasive monitoring of tumor progression and drug responses, offering new opportunities for early detection and adaptive treatment strategies. This paper provides a comprehensive review of the current landscape of cancer treatment, comparing traditional therapies with innovative, emerging approaches. By integrating knowledge from multiple disciplines such as molecular biology, oncology, and clinical research, it seeks to optimize cancer treatment strategies. Furthermore, this paper offers evidence-based recommendations for improving clinical practices and guiding future policy development, with the ultimate goal of improving patient outcomes and reducing the global burden of cancer.

2. Technological Advancements and Challenges in Mainstream Treatment Methods

2.1. Surgical Operation

About 80% of patients with cancer require at least one surgical intervention throughout their treatment [1], surgical interventions in patients with cancer covers basic procedures, such as biopsies and port-a-cath placement for chemotherapy, and curative and palliative care tumor resections [2]. Surgical intervention has long been a cornerstone in cancer treatment. For patients diagnosed at an early stage, tumor resection offers a significant opportunity for a potential cure. In recent years, continuous advancements in surgical techniques have enhanced the effectiveness of cancer treatment. The adoption of minimally invasive surgery and robot-assisted surgery has markedly improved both the safety and precision of procedures. Minimally invasive surgery, characterized by small incisions, reduces recovery time and minimizes the risk of postoperative complications. Robot-assisted surgery, with its increased flexibility and precision, facilitates the execution of complex procedures with greater accuracy, playing an especially vital role in delicate and high-risk surgeries. However, not all cancer patients are candidates for surgical treatment. When the tumor has metastasized or is deemed inoperable, the efficacy of surgery is significantly limited. Furthermore, challenges persist regarding the prevention of damage to surrounding tissues, ensuring complete excision of the tumor, and minimizing the risk of postoperative recurrence.

2.2. Radiotherapy

Radiotherapy (RT), a fundamental component of cancer treatment, is received by about half of all patients with cancer [3-5]. Radiation therapy involves the localized irradiation of tumors using high-energy rays, with the goal of either destroying cancer cells or inhibiting their viability. Over the years, this technology has seen significant advancements, particularly with breakthroughs in Stereotactic Radiosurgery and Proton Therapy. These innovative treatment methods enable more precise targeting of tumor tissues, thereby minimizing the risk of side effects and reducing damage to surrounding healthy tissues. Additionally, radiotherapy can be combined with other treatment modalities, such as chemotherapy, to produce a synergistic effect that enhances therapeutic efficacy. However, several challenges remain in the field of radiotherapy. The most pressing concern is the potential impact on critical organs when the treatment area is in close proximity to them. Furthermore, tumors may develop resistance to radiation, which can compromise treatment effectiveness. Optimizing radiation therapy to ensure both adaptability and safety for all patients remains a significant and unresolved challenge.

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2.3. Chemotherapy

Chemotherapy is one of the conventional methods to cure cancer, mainly using drugs to kill cancer cells or inhibit their proliferation. In recent years, along with the development of new drugs, the effect of chemotherapy has been improved significantly. While improving the treatment efficacy against specific cancers, novel drugs can also reduce damage to normal cells to a certain extent. However, the side effects of chemotherapy are also an indispensable problem, especially causing damage to normal tissues such as bone marrow, gastrointestinal, heart, liver, renal, neuron, and auditory tissues, etc [6]. These side effects not only can influence the life quality of patients, but also can cause the interruption of the curing process. In addition, as the complexity of cancer increases, single chemotherapy treatments often struggle to address the heterogeneity of tumors, leading to issues of drug resistance and recurrence. The problem of chemotherapy drug resistance, especially in the treatment of advanced cancers, presents a significant challenge for patients. Overcoming drug resistance and improving treatment efficacy remain crucial issues that need to be addressed in the field of chemotherapy.

3. Innovative Therapies Driven by Precision Medicine

3.1. Targeted Therapy

Targeted therapy represents a cutting-edge approach in cancer treatment, aimed at specifically targeting molecular mechanisms that drive cancer cell growth. The fundamental principle of targeted therapy involves the identification and inhibition of aberrant molecules in cancer cells using small molecule drugs or monoclonal antibodies. Unlike conventional chemotherapy, which affects both cancerous and healthy cells, targeted therapy selectively impacts tumor cells, sparing surrounding healthy tissue. Patients who received matched targeted therapies showed dramatically improved overall survival (OS) and progression-free survival (PFS) compared to those without matched therapies [7]. Recent advancements in the development of targeted small molecule drugs and monoclonal antibodies have led to significant therapeutic progress. For instance, targeted therapies targeting epidermal growth factor receptor (EGFR) mutations are now widely utilized in the treatment of non-small cell lung cancer, while HER2-targeted therapies have shown promising efficacy in breast cancer patients. Beyond directly inhibiting tumor cell growth and dissemination, targeted therapy can also modulate the tumor microenvironment, thereby enhancing therapeutic outcomes. However, challenges such as tumor cell heterogeneity and the development of drug resistance continue to limit the efficacy of targeted therapies. Addressing these obstacles and further improving the clinical benefits of targeted treatments remains a critical area of ongoing research.

3.2. Immunotherapy

Immunotherapy is a revolutionary approach in the fight against cancer, harnessing the body's own immune system to identify and eliminate cancer cells. Over the past decade, immunotherapy has emerged as a groundbreaking advancement in cancer treatment, offering new hope for patients with cancers that were previously difficult to treat. A cornerstone of immunotherapy is the use of immune checkpoint inhibitors, which target and block critical immune checkpoint molecules such as CTLA-4, PD-1, and PD-L1. These molecules normally act as brakes on the immune system, preventing it from attacking the body’s own cells, including cancer cells. By inhibiting these checkpoints, the immune system is "reawakened" and enabled to recognize and attack tumor cells more effectively. Immune checkpoint inhibitors have demonstrated remarkable clinical efficacy across a wide range of cancers, including melanoma, non-small cell lung cancer, and renal cell carcinoma, significantly improving patient outcomes.

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In addition to immune checkpoint inhibitors, other immunotherapeutic strategies, such as cancer vaccines and immune cell therapies, have also made significant strides. Cancer vaccines are designed to stimulate the immune system by introducing cancer-specific antigens, prompting an immune response that targets and destroys cancer cells. Meanwhile, adoptive immune cell therapies, particularly Chimeric Antigen Receptor T (CAR-T) cell therapy, have revolutionized the treatment of certain cancers. CAR-T therapy involves the genetic modification of a patient's T cells to express a receptor that specifically targets cancer cells. This personalized treatment enhances the patient's immune response, allowing the body to more effectively recognize and eliminate malignant cells. Both cancer vaccines and CAR-T cell therapy represent major breakthroughs in precision medicine, offering new, highly targeted approaches to cancer treatment with the potential for long-lasting remission. These therapies, by leveraging the body's immune capabilities, have not only expanded the therapeutic options available for patients but also introduced new possibilities for treating cancer in a more personalized and effective manner. As research continues to advance, the future of cancer immunotherapy holds tremendous promise for improving survival rates and transforming the treatment landscape for cancer patients worldwide. However, therapy resistance and immune-mediated side effects reduce the overall success [8]. How to overcome these challenges, optimize the effect of immunotherapy and broaden the scope of indications has become the main research focus in the field of immunotherapy.

3.3. Gene Editing Techniques

Gene editing technologies, particularly the CRISPR/Cas9 system, offer promising prospects for cancer treatment. These techniques allow precise modifications of genes within cancer cells, potentially preventing tumor initiation and progression. Specifically, CRISPR/Cas9 can be utilized to repair or knock out mutations in key oncogenes or tumor suppressor genes, such as TP53 and BRCA1, which are frequently implicated in cancer development. Initial experimental studies have demonstrated the feasibility of using CRISPR/Cas9 to target and correct these mutations. Moreover, gene editing holds potential for enhancing the anti-tumor responses of immune cells. For instance, the genetic modification of T cells can improve their ability to recognize and eliminate cancer cells. Despite these promising advances, the clinical application of gene editing technologies faces significant challenges, including concerns regarding safety, long-term stability, and ethical implications, particularly in the context of human embryos or germline editing. These issues require careful consideration as the field progresses. For example, gene editing may lead to off-target effects, and the challenges in delivery are also a problem [9]. These challenges could lead to unpredictable side effects, including the potential formation of new tumor tissues. Additionally, ensuring the controllability and long-term stability of gene editing effects, as well as addressing the ethical concerns associated with applying gene editing to human embryos or germ cells, remains critical issues that must be resolved. In light of these concerns, the clinical application of gene editing technologies should proceed cautiously, with gradual progress based on stringent safety protocols and ethical considerations, despite the promising potential they hold for cancer treatment.

4. Directions for Optimizing Treatment Strategies

4.1. Multi-modal Combined Cancer Therapy

Multi-modal combined cancer therapy is an integrated treatment approach that leverages multiple therapeutic modalities to target cancer from various angles, with the ultimate goal of eradicating the disease. The primary advantage of this strategy lies in its ability to simultaneously inhibit tumor cell growth and metastasis through different mechanisms, thereby enhancing therapeutic efficacy. For example, following surgical tumor resection, adjuvant radiotherapy or chemotherapy can effectively

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eliminate residual cancer cells, thereby reducing the likelihood of recurrence. Additionally, combining immunotherapy with targeted therapy can bolster the immune system's capacity to identify and destroy tumor cells.

However, the increased complexity and extended recovery periods associated with multi-modal therapy pose significant challenges. The combination of treatments can impose a substantial burden on patients, often leading to exacerbated side effects. For instance, chemotherapy and radiotherapy may result in severe immune suppression, nausea, vomiting, and other adverse effects. Furthermore, the success of combination therapy is contingent upon the type of cancer and its molecular characteristics, meaning not all patients will experience the same therapeutic benefit.

In summary, while multi-modal therapy presents considerable advantages in cancer treatment, achieving a balance between treatment efficacy and minimizing side effects remains a critical challenge in its clinical implementation.

4.2. Artificial Intelligence Assisted Therapy

AI has achieved huge success in the realm of medicine, especially in cancer treatment. AI can play a part in tumor prevention, screening, diagnosis, treatment, and prognosis prediction [10]. AI, through technologies such as big data analysis and deep learning, can quickly process vast amounts of medical data, assisting doctors in making precise diagnoses, treatment decisions, and outcome assessments. The application of AI in cancer diagnosis, particularly in imaging analysis, helps doctors accurately identify early tumors, even microscopic lesions, significantly improving the accuracy of early diagnosis. AI can also predict the effectiveness of different treatment methods based on a patient's genetic information, tumor type, and other data, thereby tailoring the most suitable treatment plan for the patient.

Nevertheless, the application of AI-assisted treatment also presents certain challenges and limitations. Firstly, AI technology is still in the developmental phase, and although its performance has been exceptional in specific areas, its accuracy and reliability in more complex, real-world medical scenarios have yet to be fully validated. This is particularly true when dealing with rare diseases or cancer types with unique characteristics, where AI may struggle with limited data or model inaccuracies, which can lead to sub-optimal treatment plans. Secondly, the effectiveness of AI relies heavily on the availability of large volumes of high-quality, standardized medical data. However, in many regions, medical data is neither standardized nor shared effectively, hindering the widespread deployment of AI technologies. Furthermore, the integration of AI into healthcare raises significant ethical and privacy concerns, particularly in regard to the handling of sensitive patient data. Safeguarding data security and ensuring patient privacy remain pressing issues that must be addressed to promote the safe and ethical use of AI in medical practice. Overcoming these challenges will be critical for the successful and responsible implementation of AI in healthcare systems globally.

5. Conclusion

Cancer treatment is undergoing a significant transformation, shifting from a traditional empirical approach to a data-driven, personalized model. This transition is not merely a change in treatment methods, but a fundamental rethinking of medical practices. As advancements in genomics, precision medicine, and artificial intelligence continue to accelerate, cancer therapy is moving towards individualized treatment plans that are tailored to each patient’s unique genetic profile, tumor type, and disease progression. These developments have the potential to drastically improve the accuracy and effectiveness of cancer treatment, making it more specific and targeted. However, the widespread application of personalized treatment still requires extensive clinical validation of biomarkers and robust support from big data systems.

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Currently, numerous biomarkers have been proposed for early cancer diagnosis, predicting treatment responses, and monitoring disease progression. While these biomarkers show great promise, their clinical validation is still ongoing and, in many cases, remains insufficient. As a result, there is a need for continuous testing, data collection, and clinical trials to ensure the reliability and clinical efficacy of these biomarkers in real-world settings. This ongoing validation process is crucial to building trust in the ability of personalized treatments to improve patient outcomes.

In addition to the clinical challenges, the establishment of a global cancer prevention and control network is another critical aspect of the future of cancer care. The widespread use of big data offers immense potential for global collaboration in the fight against cancer. By enabling the sharing and integration of data across borders, researchers and healthcare providers can access a larger pool of information, helping to identify patterns, trends, and treatment strategies that may be effective on a global scale. This level of data exchange will not only enhance the accuracy of diagnoses and treatment plans but also contribute to the development of more universal guidelines for cancer prevention and management.

Furthermore, cancer treatment is increasingly becoming a multidisciplinary endeavor. By integrating expertise from various fields such as genomics, imaging, pharmacology, and bioinformatics, a more holistic and nuanced approach to cancer care is emerging. Each of these disciplines brings valuable insights that contribute to more precise and effective therapies. As these technologies evolve and clinical research deepens, cancer has the potential to transform from being an untreatable, life-threatening condition to a manageable, chronic disease. With continued advancements, it is conceivable that cancer will one day be treated in a manner similar to other chronic conditions, allowing patients to live longer and healthier lives. This shift will require a global effort, involving governments, healthcare systems, and research institutions, to ensure that the benefits of personalized, data-driven cancer treatment are accessible to patients worldwide.

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