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Progress in the application of gene editing technology in cancer treatments——Taking CRISPR as an example

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Abstract. The background of CRISPR's development lies in the long-standing need for precise gene editing tools, which culminated in the revolutionary CRISPR-Cas9 system in 2012. This technology has had profound impacts on biology, medicine, and biotechnology, offering versatile applications in gene therapy, agriculture, and research across eukaryotes, prokaryotes, and archaea. In the context of cancer research, CRISPR has shown promise in understanding cancer biology, identifying therapeutic targets, enhancing immunotherapy, and potentially enabling early cancer diagnosis and personalized treatment. However, challenges remain, including the need to enhance precision, address ethical concerns, and conduct rigorous clinical trials. This article examines CRISPR's advancements in cancer treatment and concludes that, when compared to other gene editing methods, it offers benefits like robust targeting, easy operation, and efficient editing. Based on these benefits, the application prospect of CRISPR in enhancing personalized medicine, drug development, and cancer treatment is also discussed in this article. This article highlights the need for addressing precision and safety issues and the importance of interdisciplinary collaboration and stringent regulation in realizing the full potential of CRISPR in cancer treatment. In conclusion, CRISPR offers promising avenues for improving cancer treatment by enabling precise gene editing and personalized therapies. Despite the challenges, continuous advancements in technology and research, along with stricter regulation, will ensure the safe and effective use of CRISPR in cancer, providing hope for cancer patients and shaping the future of oncology research.

Keywords: CRIPR-Cas9, cancer treatments, research progress.

1. Introduction

The background of CRISPR's development stems from the long-term pursuit of gene editing needs, and with continuous exploration and iteration, the CRISPR-Cas9 system was revolutionized in 2012. This application of the natural immune system has led to scientific revolutions in biology, medicine and biotechnology by making gene editing more precise, easy and efficient [1]. CRISPR has a wide range of applications, including but not limited to gene therapy, agriculture, biological research and bioengineering. Over the past few years, CRISPR gene editing tools have found extensive applications across the three major domains of life: eukaryotes, prokaryotes, and archaea. This has proven to be of immense importance in the genetic enhancement of microorganisms and the optimal utilization of microbial resources [1]. At the same time, CRISPR has been used to modify a variety of plant species, such as crop trait improvement [2].

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Currently, despite some encouraging advances in cancer research, there are still some important issues and challenges that limit its widespread use in practical applications. The first is the accuracy and specificity of CRISPR, where non-specific cuts or incomplete repairs can occur during editing, leading to unexpected genetic variants or cell mutations. Second, CRISPR editing can raise unpredictable security concerns. Before CRISPR-Cas therapy can reach its clinical potential, it is necessary to overcome possible off-target effects, improve delivery strategies and reduce viral escape [3]. Despite some success in the lab, translating CRISPR into clinical treatment still requires rigorous clinical trials. CRISPR raises a number of ethical questions in cancer treatment, including under what circumstances the technology can be used and how to ensure it is not misused, and developing a clear ethical and legal framework is a major challenge. The use of CRISPR has far-reaching research significance and prospects in cancer treatments.

Studies have found that CRISPR technology can precisely edit cancer-related genes, delve into the biological mechanisms of cancer, find new therapeutic targets, screen out potential drugs, and enhance immunotherapy effects. In addition, CRISPR is also expected to be used for early cancer diagnosis and personalized treatment, providing patients with better treatment options. This paper analyzes the research and application of CRISPR in the field of cancer treatment in recent years, and based on these analyses, evaluates the feasibility and safety of this technology for future application to cancer treatment. These efforts are expected to open up new prospects for cancer research and treatment, providing more hope for cancer patients. An in-depth analysis of CRISPR technology’s outcomes in the realm of cancer, when juxtaposed with other technologies, readily reveals its distinct advantages. Its simplicity, efficiency, and excellent specificity have made it a major draw of attention in cancer research.

CRISPR is relatively easy to operate, allowing more researchers to quickly master and carry out a wider range of cancer research. Its efficient gene-editing capabilities allow scientists to accurately modify cancer-associated genes, reducing non-specific effects, leading to a deeper understanding of the mechanisms of cancer development. The specificity of CRISPR allows precise selection of target genes, reducing unnecessary interference and improving the accuracy of experiments. In addition, CRISPR has the potential to overcome the current challenges facing cancer research institutes, provide possibilities for innovative therapeutics, facilitate drug discovery, support personalized treatments, and provide great promise for continuous improvement of cancer treatment. Therefore, the application prospect of CRISPR in cancer is highly anticipated, which is expected to open up new paths for cancer research and treatment.

2. The mechanism of CRISPR-Cas9

The gene-editing tool, CRISPR is based on the CRISPR-Cas system. Its development purpose is to precisely target the modification of the genetic material of organisms. Scientists have engineered various versions of the CRISPR-Cas system, with the CRISPR-Cas9 system being the most prominent. This system employs a specific Cas protein known as Cas9 and a guide RNA fragment to meticulously cleave and alter the DNA of a specific gene. This technique can be used to add, delete or repair genes to make precise modifications to the genome. The CRISPR-Cas system is an acquired immune system that is widely present in prokaryotes and is used to fight foreign genetic elements. This system accounts for about 50 percent of the bacteria and 90 percent of the sequenced genomes of archaea. It comprises two primary elements: the CRISPR array and a set of CAS genes that encode the Cas protein [1]. The fundamental concept of technology combined with the CRISPR-Cas system revolves around editing the genome and controlling the physiological processes in various organisms and cells [4]. The immune system within the context of the CRISPR-Cas system can be categorized into three primary phases: adaptation, processing, and intervention. During the adaptation phase, which is also referred to as spacer acquisition, the system captures new spacers from the invading nucleic material and rapidly incorporates them into the CRISPR array. This process typically involves stable complexes comprising two Case1 units and a Case2 unit, sometimes assisted by additional proteins like Case4 and reverse transcriptase. Moving on to the second phase, the maturation of CRISPR RNA (crRNA) takes place. Initially, the entire CRISPR array is transcribed into precursor crRNA (pre-crRNA) with the guidance of embedded

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promoter elements within the guide sequence. Following this transcription, a series of ribonucleases, including Cas nucleases such as Cas6, Cas5d, and Cas12, along with non-Cas nucleases like RNase III and other RNases crucial for maintaining cellular functions (E and PNPase), aid in the conversion of precursor crRNAs into fully functional crRNAs. These mature crRNAs then associate with effector proteins or multi-subunit effector protein complexes to create ribonucleoprotein complexes (RNPs). In the final phase of target interference, RNPs bind to complementary sequences between the target nucleic material and crRNA to recognize and cleave the invading DNA or RNA. This process effectively shields foreign genetic material and accomplishes the interference mechanism [1].

3. Achievements and technical advantages of CRISPR technology

CRISPR has achieved remarkable research results in many important fields and is currently at different stages of development. In biotechnology, CRISPR-Cas technology is used to engineer cell factories that utilize C1 substrates for biomanufacturing, such as reducing greenhouse gas emissions and lowering atmospheric CO_2 concentrations [5]. In the field of agriculture, CRISPR is used to improve crops, improve the quality of crops, mainly focusing on improving the appearance, food quality, fruit substance and nutritional value of crops, improving yield and disease resistance, and some improvements crops have been put on the market [6]. In addition, CRISPR is also widely used in cancer treatment, immunotherapy for infection with viruses, and gene regulation, although some applications are still being researched and developed, CRISPR has made breakthroughs and continues to trigger global scientific research and ethical discussions [7]. Compared with ZEN and TALENs, CRISPR-Cas9 has more advantages. First, CRISPR-Cas9 is more cost-effective. Second, it has higher targeting specificity, easy design of sgRNA, and a variety of feasible editing methods, including vector system modification, direct embryonic gene editing, simultaneous introduction of multiple mutations, and base editing. These indicate the potential safety and success of CRISPR-Cas9 technology in terms of clinical applications [8].

4. CRISPR technology applications in cancer

Researchers have conducted several successful gene-editing studies using the CRISPR-Cas9 system, revealing a number of potential therapeutic targets. For example, by targeting and inhibiting cancer-driver genes, the growth rate of certain tumors has been successfully slowed. CRISPR technology is also being used to repair genetic mutations associated with cancer, providing new prospects for individualized treatment. In immunotherapy, researchers are using CRISPR to improve T-cell therapy and improve the immune system's ability to respond to cancer. Sseveral studies have explored the possibility of using CRISPR for early detection of cancer, providing earlier diagnosis and intervention opportunities by detecting specific DNA markers in body fluids. While further research and clinical validation are still needed, CRISPR brings new promise to the field of cancer treatment and is expected to improve the quality of life and survival chances of cancer patients [9]. However, the development of CRISPR for cancer faces some important problems. First, the precision and specificity of the technique still need to be improved to ensure accurate localization and treatment of tumor cells without harming normal cells. Second, CRISPR raises ethical and safety questions, including concerns about the potential risks that gene editing could bring, and the long-term effects of the treatment. In addition, clinical trials and approval processes will take time to validate the safety and efficacy of CRISPR, which could delay its widespread adoption in cancer treatment. Solving these problems requires interdisciplinary collaboration and in-depth research to ensure that CRISPR is safe and effective in the field of cancer, ultimately helping to improve the quality of life and treatment outcomes of cancer patients [10]. For some table titles and contents, the left side is set to 0.5 mm, mainly to fit the table so that the title is centered. As long as the layout can be reasonable, no indentation can be added.

5. Discussion

In order to solve the problems faced by CRISPR in cancer, researchers have taken a variety of measures. First, they continue to improve CRISPR to improve its precision and specificity [10]. For example, researchers have developed more precise variants of CRISPR, such as the base editor, for precise single-base repair, reducing unwanted genetic variation. In addition, specific recognition methods targeting tumor cells, such as the use of cancer-specific antibodies or markers to guide CRISPR editing, are expected to reduce the impact on normal cells. Second, basic research plays a key role in addressing ethical and safety issues. Researchers are delving into the effects of gene editing on the organism, including potential adverse consequences, to develop stricter ethical guidelines and regulatory policies [8]. For example, studies have found that certain variants of CRISPR may trigger undesirable cell mutations, raising alarms about the potential risks of treatment. Future trends include better application of CRISPR to personalize cancer treatment, such as by studying a patient's genome to precisely design treatment options. In addition, enhanced interdisciplinary collaboration that integrates basic research with clinical practice can help bring new therapeutic strategies to market faster. In summary, through continuous improvement of technology, deepening research and strict regulation, CRISPR has the potential to improve the future of cancer treatment by providing patients with safer and more effective treatment options in the field of cancer [9].

6. Conclusion

As a revolutionary gene editing tool, CRISPR has achieved remarkable research results in the field of cancer, providing broad prospects for future applications. By precisely editing cancer-related genes, researchers have revealed multiple therapeutic potentials, with some encouraging initial successes in clinical trials. The development of personalized treatment options, tailored to the genetic profile of the patient, will be the trend of the future, providing patients with more effective treatment options. In addition, continued improvements in CRISPR, including more precise editing tools and safer variations of the technology, will help address some of the issues currently faced, such as non-specific editing and ethical issues. To ensure the safe and sustainable use of CRISPR in cancer, interdisciplinary collaboration and stricter supervision are necessary for future research. In short, CRISPR is expected to bring more precise, personalized and effective treatments to the field of cancer, bringing more hope and opportunities to cancer patients. However, in future research, caution should also be exercised regarding the challenges and risks to ensure that widespread adoption of the technology remains centered on patient well-being. In future research, CRISPR will make more breakthroughs in the field of cancer and bring greater hope to the health and survival of cancer patients.

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