CRISPR-Cas 9 on Oncology: Current Progress and Future Direction

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Key points:

- Introduction to CRSPR
- Mechanism
- Current application in oncology
- Conclusion

Introduction

Cancer is a complex disease caused by genetic and epigenetic alterations that lead to uncontrolled cell growth. Although conventional treatments have improved patient outcomes, challenges such as toxicity, drug resistance, and limited specificity remain. CRISPR-Cas9 is a powerful gene-editing technology that enables precise modification of disease-associated genes. It has emerged as a promising tool in cancer research and therapy by allowing targeted correction of genetic mutations, disruption of oncogenes, and enhancement of anti-tumor immunity.[1]

Mechanism of CRISPR-Cas9

CRISPR-Cas9 is a genome-editing tool derived from the adaptive immune system of bacteria. Its mechanism involves three main steps: recognition, cleavage, and repair. First, a single guide RNA (sgRNA) directs the Cas9 enzyme to a specific DNA sequence by complementary base pairing. This process requires a protospacer adjacent motif (PAM), usually the 5'-NGG-3' sequence, which allows Cas9 to recognize and bind the target DNA. Once bound, Cas9 creates a double-stranded break in the DNA. The cell then repairs the break through either non-homologous end joining (NHEJ), which may disrupt the target gene, or homology-directed repair (HDR), which enables precise gene correction when a repair template is available. This ability to accurately modify specific genes has made CRISPR-Cas9 an important tool in cancer research and the development of targeted therapies.[2]

Delivery Systems for CRISPR Therapeutics

Efficient delivery of CRISPR-Cas9 components into target cells is essential for successful cancer therapy. Delivery systems are classified into viral and non-viral methods. Viral vectors, such as adeno-associated viruses (AAV) and lentiviruses, provide high gene-editing efficiency but are associated with risks including immunogenicity, insertional mutagenesis, and limited cargo capacity. Non-viral methods, including lipid nanoparticles and electroporation, offer improved safety but generally have lower delivery efficiency. Recent advances in nanotechnology have improved the effectiveness of non-viral delivery systems.[2]

Viral vectors achieve higher gene-editing efficiency (approximately 85–90%) than non-viral methods (60–80%), but their clinical use remains limited by immune reactions and the potential risk of genome integration.[2]

Current Applications in Oncology

Targeting Oncogenes and Tumor Suppressor Genes

CRISPR-Cas9 enables precise editing of cancer-related genes, including oncogenes and tumor suppressor genes. Knockout of oncogenes such as **KRAS, MYC,** and **EGFR** has been shown to inhibit tumor growth, while restoration of tumor suppressor genes such as **TP53, BRCA1,** and **PTEN** may help restore normal cell cycle regulation and apoptosis. These strategies have shown promising results in preclinical studies, highlighting the potential of CRISPR-Cas9 in precision oncology.[1,3]

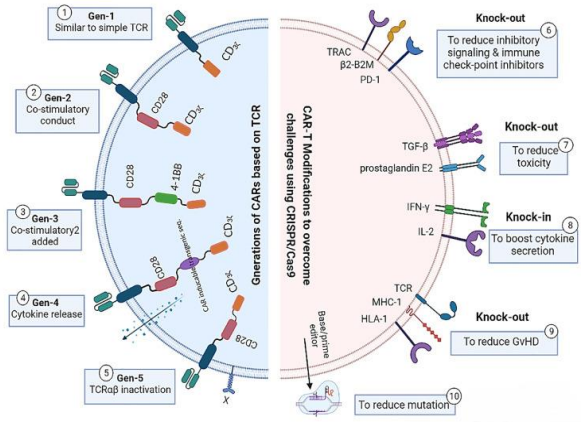


Figure 1: *Some everyday measurements for treating dementia*[4]

CRISPR in CAR-T Cell Therapy

One of the most advanced clinical applications of CRISPR-Cas9 is **chimeric antigen receptor T-cell (CAR-T) therapy**. In this approach, a patient's T cells are genetically modified to improve their ability to recognize and destroy cancer cells. CRISPR can remove inhibitory genes such as **PD-1**, enhancing anti-tumor activity and reducing immune rejection. CRISPR-engineered CAR-T cells are currently being evaluated in clinical trials for leukemia, lymphoma, multiple myeloma, and several solid tumors.[3]

Enhancing Cancer Immunotherapy

CRISPR-Cas9 is widely used to enhance cancer immunotherapy by genetically modifying immune cells to produce stronger and more durable anti-tumor responses. For example, deleting immune checkpoint genes such as PD-1 improves the ability of T cells to recognize and eliminate cancer cells. Researchers are also investigating CRISPR-based modifications that increase immune-cell persistence and reduce treatment-related toxicity.

Personalized Cancer Medicine

CRISPR-Cas9 supports precision oncology by enabling treatments tailored to the genetic profile of an individual patient's tumor. This approach allows targeted therapies that may improve treatment outcomes while reducing adverse effects.[1,4]

Early Cancer Diagnosis

CRISPR-based diagnostic platforms, such as **SHERLOCK** and **DETECTR**, enable rapid and sensitive detection of cancer-associated DNA and RNA mutations from tissue samples or liquid biopsies. These technologies may support earlier diagnosis, disease monitoring, and detection of cancer recurrence.[1,3]

Conclusion

CRISPR-Cas9 has become a valuable tool in modern oncology, enabling precise gene editing for cancer research and treatment. Its applications include targeted gene therapy, CAR-T cell therapy, personalized medicine, and early cancer diagnosis. Although challenges such as off-target effects, safe delivery, and ethical concerns remain, ongoing research continues to improve its clinical potential. CRISPR-Cas9 is expected to play an important role in the future of precision cancer therapy.[1-4]

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