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CRISPR-Cas9–Mediated Gene Editing for Targeted Cancer Therapy

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Introduction

Advances in gene-editing technologies have opened new frontiers in the development of targeted cancer therapies, with CRISPR-Cas9 emerging as one of the most powerful and versatile tools available. CRISPR-Cas9, originally discovered as a bacterial defense mechanism, enables precise editing of specific DNA sequences by guiding the Cas9 nuclease to targeted genomic regions. In cancer research, this technology has unlocked unprecedented possibilities for correcting oncogenic mutations, disrupting cancer-promoting pathways, and enhancing the effectiveness of immune-based treatments. Unlike traditional chemotherapy or radiation, which impact healthy and cancerous tissues alike, CRISPR-Cas9 allows for highly selective interventions based on genetic profiles. As a result, it offers the potential for personalized, minimally invasive therapeutic strategies that target tumors at the molecular level. With ongoing advancements in delivery systems, specificity, and safety, CRISPR-Cas9 is rapidly evolving into a transformative approach for precision oncology [1].

Description

One of the primary applications of CRISPR-Cas9 in cancer therapy is the direct correction or knockout of genes implicated in tumor development. Many cancers are driven by mutations in oncogenes such as KRAS, EGFR, or BRAF, or by the loss of tumor suppressor genes like p53 and PTEN. Using CRISPR-Cas9, researchers can disable harmful mutations, restore normal gene function, or introduce protective genetic changes within cancer cells.

This targeted gene editing disrupts the molecular mechanisms that enable uncontrolled cell proliferation. Furthermore, CRISPR can be used to sensitize cancer cells to existing treatments by knocking out drug-resistance genes, thereby enhancing the efficacy of chemotherapy or targeted drugs. By precisely editing the tumor genome, CRISPR-Cas9 holds promise for developing highly personalized therapies that align with each patient's genetic tumor profile [2].

Beyond editing cancer cells directly, CRISPR-Cas9 plays a significant role in advancing immunotherapy. Immune checkpoint therapies and CAR-T cell therapies have shown remarkable success, yet they face challenges such as immune evasion by tumors and limited T-cell persistence. CRISPR-Cas9 enables the engineering of immune cells with enhanced antitumor capabilities for example, by deleting genes that suppress T-cell activity or by inserting synthetic receptors that recognize tumor-specific antigens. Edited CAR-T cells generated through CRISPR exhibit stronger cytotoxicity, improved tumor recognition, and resistance to tumor-induced immunosuppression [3].

A major consideration in CRISPR-mediated cancer therapy is the efficient and safe delivery of the CRISPR components to the desired tissues. Viral vectors, lipid nanoparticles, and nonviral delivery systems are currently being explored to ensure accurate targeting while minimizing off-target effects. Improvements in Cas9 variants, guide RNA design, and delivery technologies help enhance gene-editing precision and reduce unintended mutations. Preclinical studies have demonstrated promising outcomes, and early-phase clinical trials are underway to evaluate the safety, feasibility, and therapeutic potential of CRISPR-based cancer treatments in humans [4,5].

Conclusion

In conclusion, CRISPR-Cas9–mediated gene editing represents a groundbreaking advancement in targeted cancer therapy, offering unprecedented precision in modifying genetic pathways that drive tumor growth. By enabling direct tumor gene correction, enhancing immune responses, and improving therapeutic sensitivity, CRISPR-Cas9 paves the way for highly personalized and effective cancer treatments. While challenges remain in ensuring safe delivery and minimizing off-target effects, ongoing research continues to refine the technology.

Acknowledgement

None

Conflict of Interest

None

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