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Ethical boundaries in immune-based genetic editing.

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Introduction

Advances in genetic engineering have revolutionized our understanding and manipulation of the immune system. Techniques like CRISPR-Cas9 and base editing have opened the door to precise modifications of immune cells—most notably in cancer immunotherapy, autoimmune diseases, and vaccine development. However, these unprecedented capabilities raise critical ethical questions. Where do we draw the line between healing and enhancing? Between therapeutic necessity and genomic ambition? As immune-based genetic editing enters clinical reality, defining its ethical boundaries becomes imperative [1, 2].

Genetic editing of immune cells has shown tremendous promise. In particular: CAR-T cell therapy involves modifying T cells to express synthetic receptors, enabling them to target and destroy cancer cells with high specificity. CRISPR applications now allow correction of disease-causing mutations in primary immune disorders such as severe combined immunodeficiency (SCID). Gene editing can also be used to reduce transplant rejection or engineer universal donor cells, improving access and efficacy of immune-based treatments [3, 4].

These breakthroughs blur the distinction between traditional medicine and what was once considered science fiction. One central ethical question is whether immune-based editing should be limited to therapeutic use treating disease or extend into enhancement, such as boosting immunity beyond natural limits. While preventing HIV through CCR5 gene deletion may be defensible, enhancing immune responses to increase athletic performance or longevity poses deeper moral dilemmas. Enhancement may lead to new forms of social inequality or pressure to genetically conform to new standards of health [5, 6].

Somatic editing affects only the treated individual, whereas germline editing alters heritable DNA and impacts future generations. Somatic immune editing such as modifying a patient's T cells—is ethically permissible in many jurisdictions, provided it is safe and voluntary. Germline editing, however, sparks intense debate. Its use to edit immune-related genes for disease resistance e.g. immunity to malaria or HIV raises concerns about unintended mutations, intergenerational consent, and eugenics [7, 8].

Given the complexity of immune-based genetic editing, informed consent becomes a cornerstone of ethical practice. Patients must understand: Ethical implementation requires considering global access. Advanced immune-based genetic therapies are expensive and infrastructure-intensive. Without equitable distribution, they risk widening health disparities. For example, CAR-T cell therapy costs over $400,000 per treatment in some countries, limiting access to affluent populations [9, 10].

Conclusion

Should the ethical boundary include mandatory sharing of data, patents, or techniques? Many argue that life-saving immune-based therapies should not be monopolized or withheld due to cost. Another ethical minefield is dual-use research—where immune editing could be exploited for harmful purposes: Enhancing immune responses for biological warfare or performance enhancement in combat. Designing pathogens that evade genetically engineered immunity. International oversight and regulation become critical to prevent misuse and protect human rights.

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