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Microgravity Experiments from Sub-Orbital to Orbital Platforms (3)

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DROP TOWER-BASED GENE DELIVERY TECHNOLOGY COMBINING GRAVITY CHANGES AND ELECTROPORATION FOR CELL THERAPY

Abstract

1. Background

One of the key challenges in space exploration is maintaining human health in microgravity. Studying the effects of gravity changes on biological systems is crucial for applying earth-based medical knowledge to space environments. However, opportunities to study microgravity are limited, as free fall is one of the few ways to simulate it, and its duration is short. To address this limitation, repetitive free-fall experiments have been explored. Parabolic flights provide repeated microgravity exposure, effectively simulating space conditions. Similarly, drop towers can be used for repeated free-fall experiments, extending microgravity duration and enabling a more comprehensive study of biological changes, including gene expression alterations.

2. Drop Tower-Based Gravity Change and Electroporation(Gravito-poration)

Cell therapy, which utilizes stem or immune cells, requires efficient gene delivery. Current methods like electroporation, lipofection, and viral transduction face challenges in toxicity, cost, and scalability. We propose a novel gene delivery method that combines gravity changes using drop towers with electroporation. Repetitive gravity shifts mechanically deform cell membranes, creating temporary discontinuities that facilitate gene entry. This reduces the required electric field strength, minimizing cell damage while maintaining delivery efficiency. Conventional electroporation relies on high electric fields, which often harm primary and stem cells. By leveraging gravity-induced deformation, this method improves membrane permeability and enhances gene transfer efficiency while ensuring high cell viability.

3. Future Prospects

Gravito-poration is a game-changing approach that overcomes traditional gene delivery limitations. This method is particularly promising for next-generation cell therapies, such as CAR-T and CAR-NK, by ensuring high cell survival and efficient gene integration. By enhancing scalability and reliability, this technology can support mass production and stable supply of immune cell therapies, driving advancements in next-generation cell-based treatments.