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Sonic-Driven Microgravity Assisted Tissue Chip Models for the Effects and Countermeasures of Space Radiation on Human T-Cell Distribution and Functions

Astronauts face unique challenges during space travel, including exposure to microgravity and space radiation, which can significantly impact their immune systems. To better understand these effects, we propose a novel sonic-powered microgravity-assisted lymph node (LN) tissue chip model to investigate human T-cell responses to cosmic radiation.

Our innovative approach combines a 3D-printed microfluidics-based LN tissue chip with an acoustic-levitated microgravity simulator, offering a highly biocompatible and non-contact microgravity environment. The LN tissue chip replicates key features of the native lymph node, including its spatial microenvironment, compartmentalization of immune cells, extracellular microenvironment, and continuous dynamic fluid flow. The high throughput, robustness, and reproducibility of the 3D printed tissue chips enable the mass fabrication of structures with remarkably large domain sizes (over cm2).

By systematically controlling various parameters such as gravity level, system perfusion, cell staining, cell tracking, and space radiation dose, we aim to elucidate the role of each factor in the immune response. We will investigate the behavior of Jurkat T cells and Raji B cells under simulated microgravity and space radiation conditions using advanced imaging techniques. The transparent, 3D-printed LN tissue chips offer extraordinary optical properties, allowing for advanced imaging and analysis of immune cells under these unique environmental conditions. The success of this research will contribute to a deeper understanding of the effects of ionizing radiation on the human immune system and radiation carcinogenesis, aiding in the development of personalized radiological countermeasures to protect astronauts during long-duration space travel. The developed technology also has potential applications in various areas of biomedicine, such as drug discovery, toxicity testing, and disease modeling. Our findings will provide valuable insights into the mechanisms underlying the immune system's response to space radiation exposure and how this response can be modulated to ensure the health and well-being of astronauts during long-term space missions.