Optimizing Stem Cell Delivery for Ischemic Stroke Treatment Using a Microfluidic Model

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Background: Ischemic stroke, the most common form of stroke, remains a leading cause of disability and death worldwide. Despite advancements in thrombolytic therapy and mechanical thrombectomy, effective treatments that enhance long-term recovery are limited. Stem cell therapy, particularly using mesenchymal stem cells, offers promising potential for neural repair and functional recovery. However, challenges in efficiently delivering these cells to the brain, due to the blood-brain barrier (BBB) and systemic clearance, hinder clinical translation.

Aims: This study aims to develop and validate a microfluidic model to optimize stem cell delivery via thrombectomy catheters for ischemic stroke treatment. It seeks to replicate the cerebral circulation, providing a platform for testing and refining stem cell delivery techniques to improve therapeutic outcomes.

Methodologies: To imitate stem cell transport in an ischaemic stroke, the microfluidic model was created and built with an arterial-brain unit fabricated by 3D printing resin and fusion software. It was fit with a polymer membrane of 10 μm pore size to mimic the damaged artery wall in BBB, a brain chamber underneath and an infusion pump. Model cell supply of stem cells with clinically relevant sizes were used for infusion and model's functionality was tested by measuring infusion rates, volumes, and liquid/cell crossing via membrane.

Results: The model passed initial testing with no leakage and membrane functionality that replicated the blood-brain barrier. Higher infusion rates caused more cells to traverse the artery wall to the brain, verifying the idea that high flow rates are more effective for cell migration across membranes. The concept worked because cell migration increased proportionally with flow rates without cellular damage or aggregation.

Conclusions: This study highlighted that higher infusion rates resulted in a greater number of cells crossing arterial wall to the brain, challenging the assumption that longer contact times (slower flow rates) would be more effective. The successful bubble removal and liquid flow control demonstrated the model’s dependability and application for therapeutic research. These findings allow for additional exploration.

Key words: Ischemic stroke, stem cell therapy, microfluidic model, thrombectomy catheters, infusion parameters