An Experimental and Computational Platform for Neurapheresis: Cerebrospinal Fluid Filtration Device and Protocol Optimization

Shivanand P. Lad MD, PhD; Lucas R Sass; Mohammadreza Khani; Shavaine Byass; Aaron McCabe; Laura Zitella Verbick; Olivier Baledent; Bryn A Martin PhD

Department of Neurological Surgery, Duke University, Durham, NC, USA?; Department of Biological Engineering, University of Idaho, ID, USA; Minnetronix Neuro Corporation, St. Paul, MN, USA; Bioflow Image, University Hospital, Amiens, France

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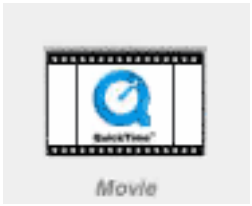
Introduction

Addressing unwanted solutes within the cerebrospinal fluid (CSF) has potential to help treat many CNS diseases including: subarachnoid hemorrhage (SAH), meningitis and leptomeningeal metastases. Neurapheresis is a novel platform for CSF filtration-based therapeutics. Here, we present a platform for device optimization.



3D-printed phantom detail and simulated SAH timelapse.

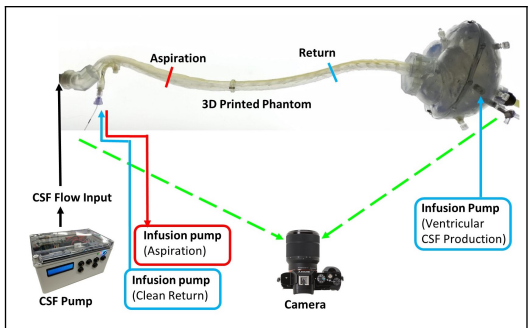


Figure 1. In-vitro system block diagram

Methods

In-vitro model: A 3D-printed phantom of the CSF system was contructed from T2 MR-image segmentation. The dual lumen catheter was inserted and each lumen connected to an infusion pump to create a filtation loop. A third infusion pump mimicked CSF production in the lateral ventricles. Digital image subtraction was applied to quantify spatial-temporal tracer distribution.

Computational model: A bi-phasic computational fluid dynamics simulation with fluid consisting of blood and CSF was setup using the digital geometry and boundary conditions applied in the in-vitro system.

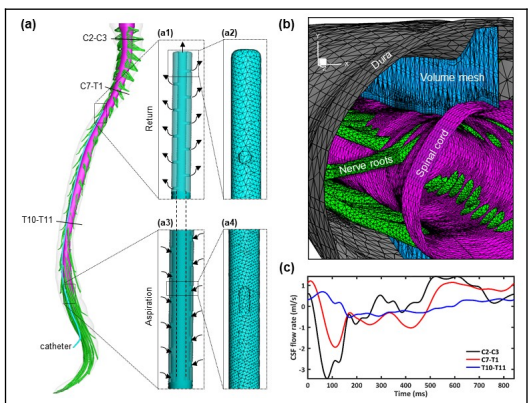


Figure 2. (a) Spinal geometry. (b) Computational mesh. (c) Flow waveforms.

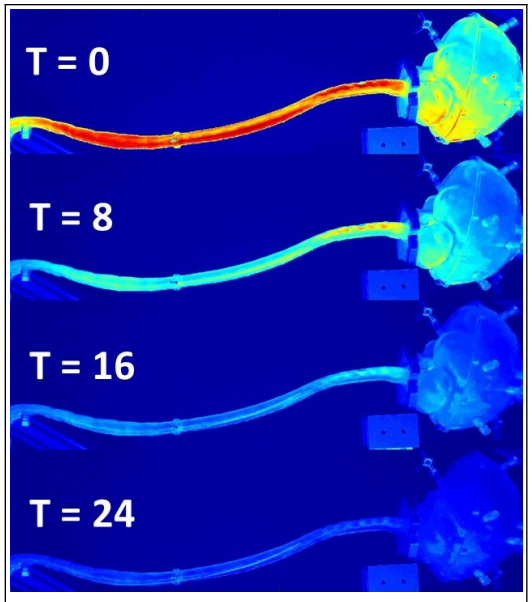


Figure 3. In-vitro neurapheresis data over 24 hours.

Results

Computational model: Numerical modeling provided detailed quantification of the CSF flow field including steady-streaming flow dynamics and spatial-temporal distribution of blood within the CSF.

In vitro model: In vitro results provided visualization of tracer spread with high spatiotemporal resolution throughout the entire CSF system under various protocols.

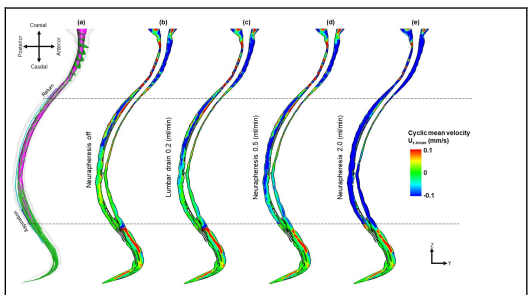


Figure 4. Neurapheresis incresed streadystreaming flow magnitude.

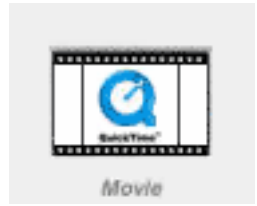


Figure 5. Timelapse CFD simlation of neurapheresis.

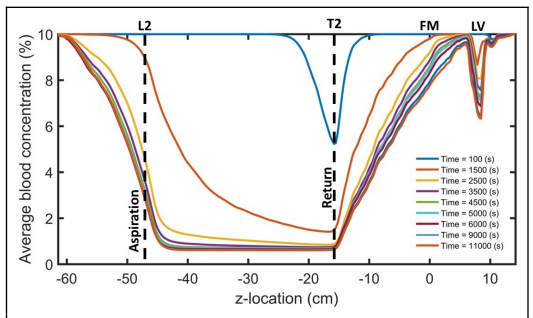


Figure 6. Computational results for blood clearance. Primary effects were seen between the return and aspiration levels. Clearance in the lateral ventricals (LV) was due to CSF production.

Conclusions

The provided platform can allow parametric testing to better understand CSF dynamics and optimizing Neurapheresis for current and future indications.

References

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