Team B10: Novel Ventricular Catheter - Optimized Anti-Clotting Cerebrospinal Fluid Drainage

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A. JAMES CLARK SCHOOL OF ENGINEERING

VentriculoMinds
BIOE485/6 Capstone
Ventricular Neurocatheter Project

THE FISCHELL DEPARTMENT of BIOENGINEERING

UNIVERSITY OF MARYLAND

Motivation & Objectives

The current treatment for cases of acute elevated intracranial pressure caused by excessive cerebrospinal fluid, blood or other fluids typically involves the placement of an external ventricular drain/catheter to relieve the pressure buildup and drain the excess fluid.

Problems with current catheters:

- **Rely entirely on side drainage ports** along the shaft of the catheter to evacuate fluid
- Side drainage ports are **prone to occlusions** by blood clots and brain tissue
- Frequent drainage and **replacements** are necessary
- 20% of patients develop **permanent occlusion**
- 41% of catheters experience at least 1 temporary occlusion

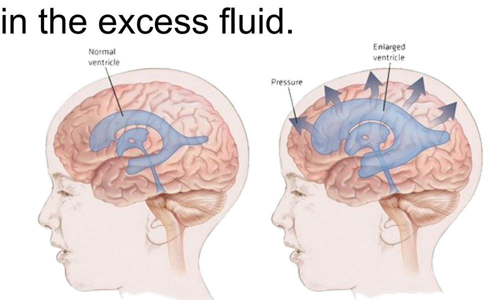

Figure 1. Pressure exerted on the brain as a result of cerebrospinal fluid build up

Our solution is a **novel ventricular catheter** with a **removable tip** that introduces **an additional drainage port**, decreasing occlusion frequency.

Methods

Based on feedback from Dr. Serra and analysis of existing neural catheters, the below table outlines desired and necessary specifications for the novel ventricular catheter.

Table 1. Design criteria for Novel Neural Ventricular Catheter

Parameter	VentriculoMinds Neural Catheter
Achieved	
Cost	≈ $15.00
Number of Side Holes	4 per side (16 total)
Size of Side Holes	1.40 mm
Tip Diameter	1.70 mm tapered to 3.00 mm catheter diameter
Removable Tip	Yes
In Progress	
Occlusion Rate (14-day testing interval)	Currently undergoing testing
Material	Flexible V2 Resin
Biocompatibility	Future iterations

Table 2. Fluid simulation parameters

Parameter	Value
Analysis Type	Internal Analysis
Fluid	Water
Flow	Laminar
Pressure	104325 Pa
Temperature	37°C

Visual comparison of standard catheter to VentriculoMinds catheter with and without artificial occlusions suggest that **distal hole is functional** for sufficient flushing

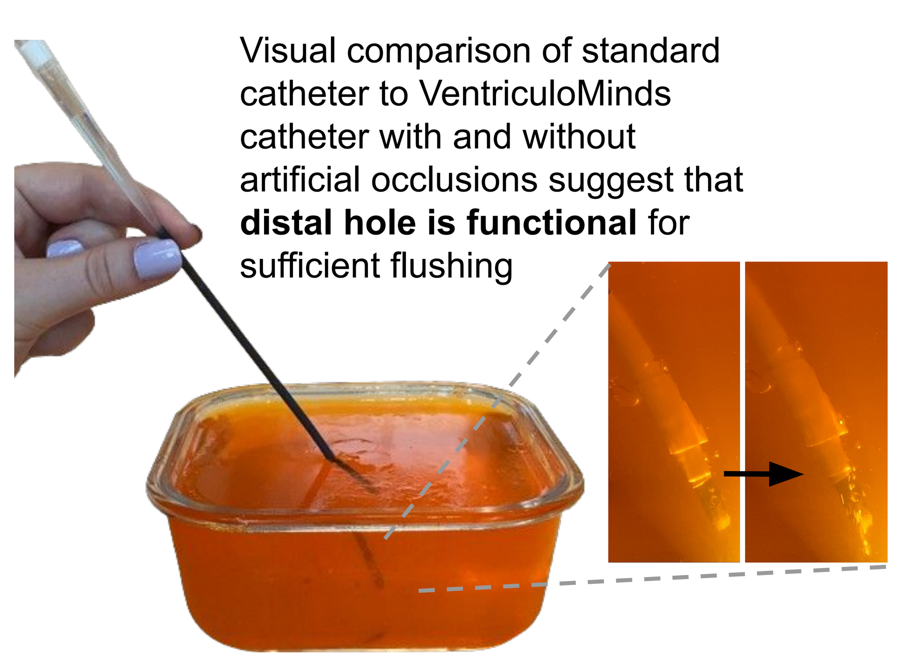

Figure 2. Benchtop flushing qualitative test

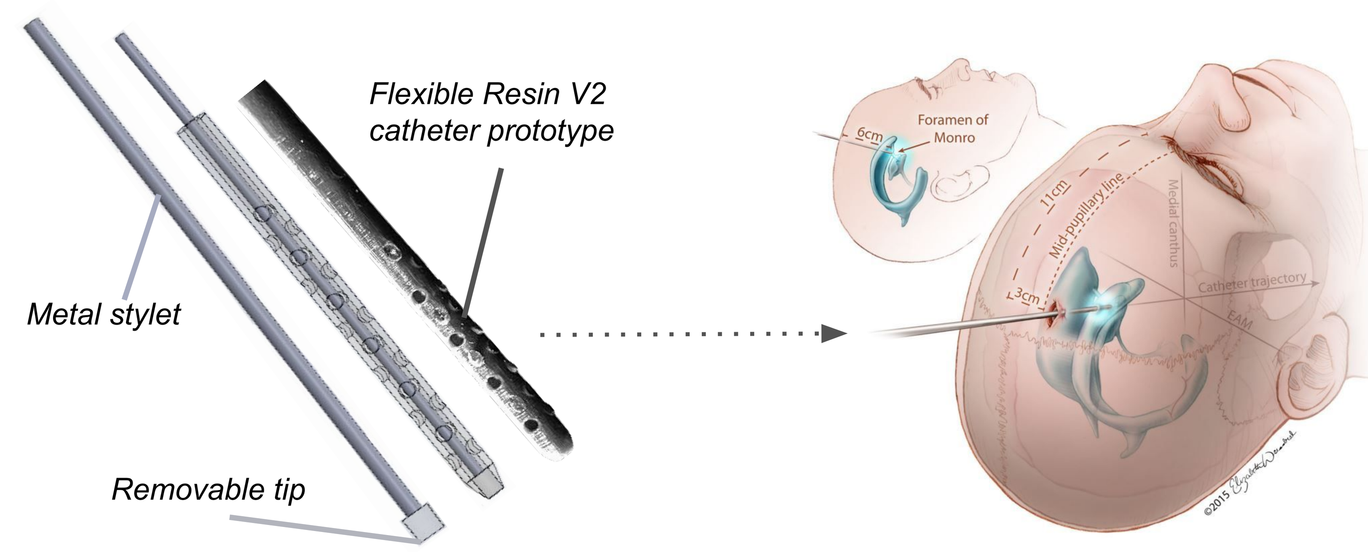

Figure 3. 3D CAD rendering juxtaposed with physical catheter prototype along with depiction of application for external ventricular shunt drainage procedure

Results

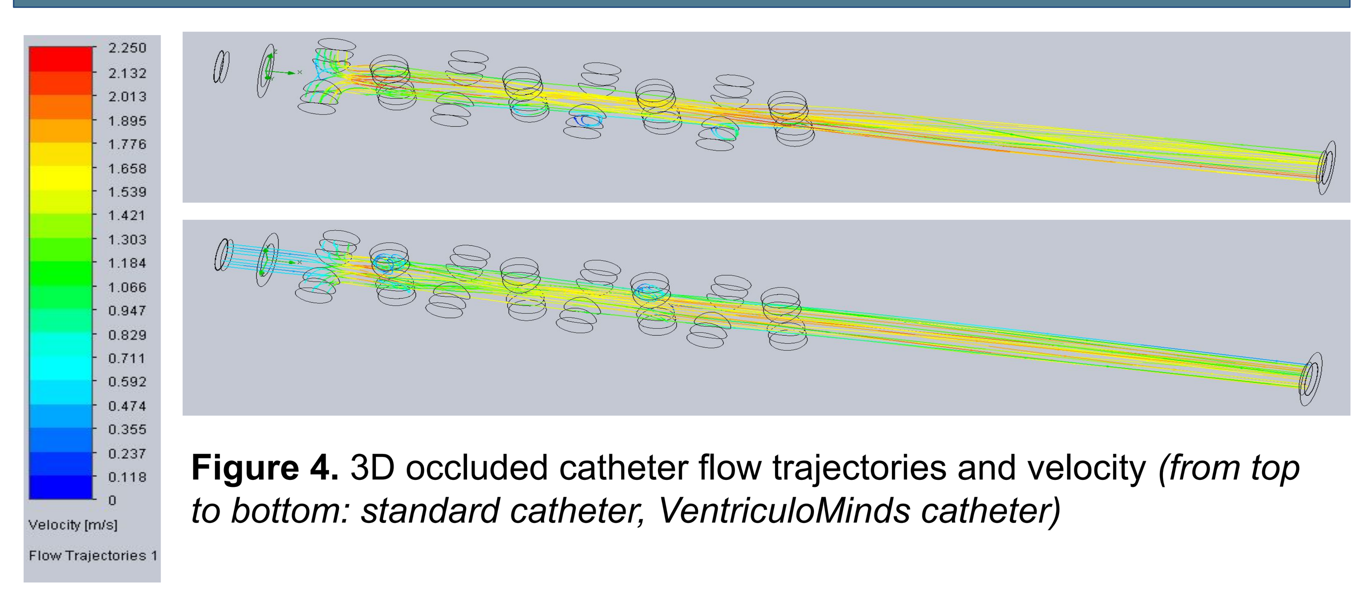

Figure 4. 3D occluded catheter flow trajectories and velocity *(from top to bottom: standard catheter, VentriculoMinds catheter)*

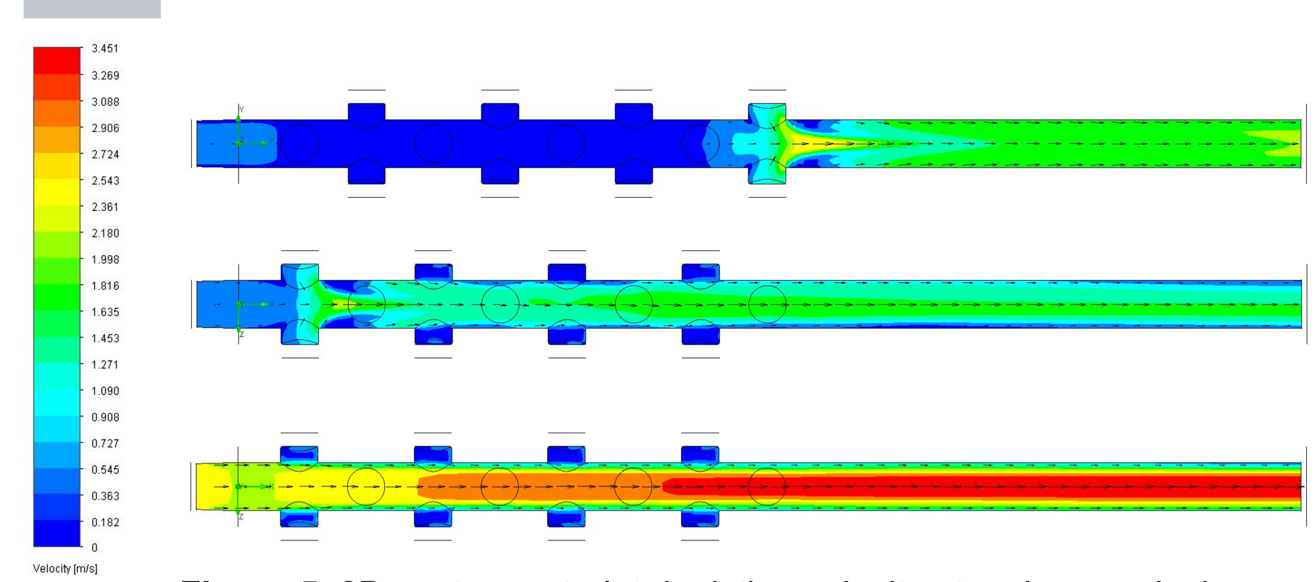

Figure 5. 2D contour cut-plot depicting velocity at various occlusion stages *(from top to bottom: not occluded, first 14 holes occluded, fully-occluded excluding distal tip)*

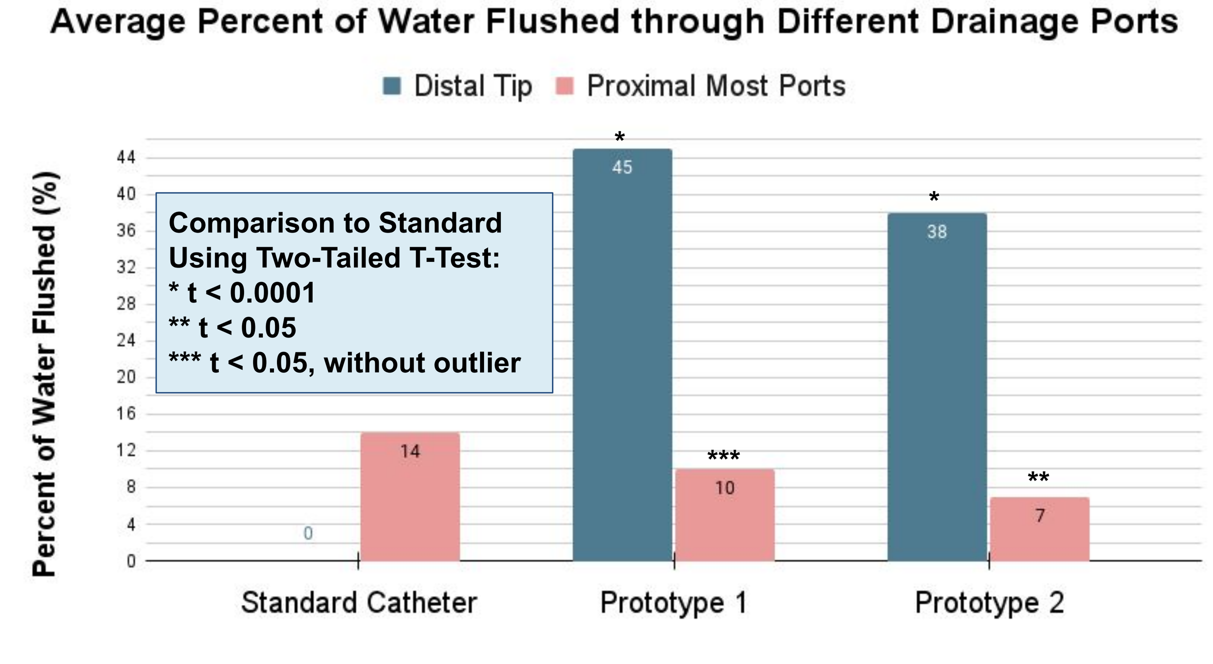

Figure 6. Preliminary benchtop drainage volume comparison

Bioethical Implications

Neurosurgeons, on a global scale, would significantly reduce/eliminate shunt replacements *without* needing to learn a new protocol using our occlusion-resistant catheter, improving patient outcomes and surgical success.

Current ventricular catheter manufacturers are welcome to partner with us to collaborate on our pending patent, outsource our technology, and assist with **future clinical trials**.

Shock trauma center patients at the University of Maryland School of Medicine and other **emergency patient intake centers** would have a reduced risk of bacterial infections, hemorrhaging, and stress imposed on the blood brain barrier, starkly **improving and safeguarding patient survival**.

Conclusions

The novel VentriculoMinds ventricular catheter can:

- **Improve Cerebrospinal Fluid Drainage Rates**
- **Reduce Occlusion Rates**
- **Improve Patient Outcomes**
- **Reduce Infection and Tissue Damage**

Moreover, data gathered from testing indicates that the VentriculoMinds catheter possess the capability to establish a **secondary defense mechanism** in the event of occlusion of the side holes. After the stylet is removed, the fluid from flushing will be able to escape through the distal orifice. The catheter was initially fabricated via 3D printing with Flexible Resin V2 (Formlabs 3B), however our future strategy is to mass manufacture our ventricular catheters via **silicone molding**.

Future Work

Manufacturing

- Establish the most cost efficient and accessible manufacturing of the device
  - Investigating methods on printing/producing the catheter in silicone (industry standard) and determining how to adhere metal tip to stylet

Additional Testing

- Conduct *in vitro* drainage evaluation via shunt system model testing with collaborators from Johns Hopkins University (JHU)
- Conduct tract hemorrhage *in vitro* tests via ReFlow system at JHU for shunt flushing confirmation
- Tissue testing with a human cadaver brains and/or pig brains (R&D milestone)

Patent Processing & Research

- Continue with the process of filing for a patent and continue communication with innovation manager
- Begin writing manuscript on in depth *in vitro* and CAD CFD results regarding catheter function, capacity, and immediate clinical translation.

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