Motivation

An abnormal accumulation of CSF leads to a condition known as Hydrocephalus. Over 150,000 people are diagnosed with this disease in the U.S. each year.

The current treatment method for all types of Hydrocephalus incorporates an intracranial pressure based shunt. Frequent problems encountered with this therapy include:

- Under-drainage or Over-drainage possibly leading to fatality.
- Multiple shunt revisions which require surgery.
- (The average lifespan of a shunt is five years).
- For adults: Complication rate = 35 %.
- For children: Failure rate = 50%.

To improve treatment options for patients suffering from Hydrocephalus we propose to:

- Measure volume changes regardless of pressure changes.
- Improve lifespan of treatment method.
- Verify the theoretical pressure-volume correlation to better understand Hydrocephalus dynamics

Solution Approach

With the following constitutive relationship:

\[ \mathbf{J} = \sigma \mathbf{E} \]

And since the gradient of the scalar potential is the electric field vector:

\[ \mathbf{E} \propto \nabla \Phi \]

Provided that the electric field remains constant: an expansion of the ventricle will lead to a change in the electric field distribution.

Conductance values of Cerebrospinal fluid (CSF) and brain matter (gray and white matter) in animal and human brain tissues. Measured vs published data.

Conductance Ratio

<table>
<thead>
<tr>
<th>Biological Tissue</th>
<th>Sensor Measured values of Conductance</th>
<th>Published values of Conductance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conductivity of gray and white matter (brain tissue):</td>
<td>0.172 ± 0.078 mS</td>
</tr>
<tr>
<td>2</td>
<td>Conductivity of Cerebrospinal fluid</td>
<td>2.01 ± 0.10 mS</td>
</tr>
</tbody>
</table>

Conclusions and Future Directions

Promising experimental and simulation results show that the conductance-volume relationship for Hydrocephalus patients can be used as a treatment option.

Future Directions include:

- Implementation of a microcontroller and shunt for control of ventricular volume.
- Microfabrication of sensor along with wireless data transmission.
- Dynamic system to measure sensor stability over time.
- Position of electrode placement and optimization of conductance-volume relationship.
- Animal Experiments.

Hydrocephalus Case Study

Boundary conditions and material properties used for computer simulations using Finite Element Analysis.

Conductance Ratio

<table>
<thead>
<tr>
<th>Condition</th>
<th>Gel Phantom Cavity</th>
<th>Human Brain Hydrocephalus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neumann</td>
<td>( \mathbf{J} \propto S \sigma )</td>
<td>( \mathbf{J} \propto 16.66 , A/m^2 )</td>
</tr>
<tr>
<td>Dirichlet</td>
<td>( V = V_{CSF} )</td>
<td>( V = 0 , V )</td>
</tr>
<tr>
<td>CSF Conductivity</td>
<td>0.2 mS</td>
<td>0.2 mS</td>
</tr>
<tr>
<td>Brain Tissue</td>
<td>1.13 mS</td>
<td>1.13 mS</td>
</tr>
</tbody>
</table>

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