Optic Nerve Sheath Mechanics in VIIP Syndrome

**BACKGROUND – VIIP Syndrome**

Visual Impairment and Intracranial Pressure (VIIP) syndrome results in a loss of visual function and occurs in astronauts following long-duration spaceflight. Understanding the mechanisms that lead to the ocular changes involved in VIIP is of critical importance for space medicine research.

Cephalad fluid shift hypothesis

In microgravity, the pressure gradient in the body is significantly reduced, resulting in higher pressures in the head (increased intracranial pressures, ICP)

VIIP occurs in ~40% of US astronauts

Some astronauts present with optic nerve distension and/or a kink in the optic nerve after return to earth strongly suggesting that axial distension and tissue remodeling in response to ICP increases may be taking place.

**METHODS – Mechanical Testing**

- CSF pressure was cycled between 0-60 mm Hg at different IOPs
- Axial stretch was controlled via micrometers
- Outer diameter of nerve sheath was recorded
- Axial force was measured with a force transducer

**RESULTS**

**Mechanical Properties**

<table>
<thead>
<tr>
<th>Pressure (mmHg)</th>
<th>Force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>2.5</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3.5</td>
<td>3</td>
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<tr>
<td>4</td>
<td>4</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Pressure (mmHg)</th>
<th>Cauchy Stress, σ_c (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>0</td>
</tr>
<tr>
<td>0.3</td>
<td>10</td>
</tr>
<tr>
<td>0.4</td>
<td>20</td>
</tr>
<tr>
<td>0.5</td>
<td>30</td>
</tr>
</tbody>
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**Axial alignment of collagen fibers in the dura**

(Second Harmonic Generation)

- Specimen bath/mounted porcine dura
- Pressure transducers
- CCD camera
- Syringe pump
- Light source

**In vivo axial stretch measurements**

\[ \lambda_x = \frac{l_d}{l_o} \approx 2.0 \]

\( l_d \): stretched length
\( l_o \): undeformed length

**CONCLUSIONS**

- Large in vivo axial stretch (~100%)
- Large deformations occur at pressures 0-10 mm Hg (~80%)
  - Consistent with changes seen in humans in response to increases in ICP
- High variability
  - Could be due to dura not being a load bearing structure, so the structural integrity is not preserved between samples
- High variation in mechanical properties could explain why some astronauts get VIIP whereas others do not
- Axial orientation of the collagen fibers and a lack of circumferential cross-fibers could lead to significant circumferential distension of the dura during increases in ICP
  - Remodeling would occur to lessen the tension and would result in the kink seen in astronauts with VIIP

Including these observations into computational models of the ONS will help improve their accuracy and enable prediction of possible risk factors of VIIP.