Phantom Model of Intracranial Dynamics

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Background

- Computational and analytical models can give otherwise not available insight into intracranial dynamics
- Such models allow for variation analysis of individual factors that influence intracranial pressure (ICP) and cerebrospinal fluid (CSF) flow
- However, they are not ideal for evaluate medical devices that influence ICP and CSF dynamics
- Animal and human studies are expensive, and raise ethical concerns
Objectives

- To develop a modular phantom platform for evaluating, improving and developing medical devices that influence intracranial dynamics
- To validate an initial configuration of this phantom for the reproduction of normal physiologic conditions

Bottan et al. (2012), *IEEE T Biomed Eng*, E-Pub ahead of print
Phantom Model Setup

- Flow Meter
- Pulsatile Pump
- Compliances
- Peristaltic Pump
- Subarachnoid Space
- ICP monitoring
- Flow Meter
- Pulsatile Pump
- Spinal Compliance
- Valves
- Pressure Sensors
- SAS Compliance
- SAS
Cranial Space

- Access for CSF production
- Ventricular Lumen
- Access for Spinal Compliance
- Exposed Surface of Silicone Brain
- Access for Pressure Sensors
- Skull Surface
- Access to SAS
- Cisterns
Cranial Space

- Skull: Generic plastic model
- Brain: Sylgard 527 Silicone *

* Ma et al. (2010), *Comput Method Biomech* 13:783ff
** Brands et al. (1999), 43th Stapp Car Crash Conf
Ventricular System
Ventricular System
Subarachnoid Space / Cisterns

- Volume estimated based on MRI data
- Hydraulic resistance estimated based on flow simulations

Gupta et al. (2010), *J Royal Soc Interface* 7:1195ff
Gupta et al. (2009), *ASME J Biomech Eng* 131:021010
Cisterns

\[ V = 24 \text{ ml} \]
Subarachnoid Space
Subarachnoid Space

\[ r = 0.5 \text{ mm} \]
\[ L = 1.5 \text{ mm} \]
\[ k = 1.7 \cdot 10^{-8} \text{ m}^2 \]
\[ V = 124 \text{ ml} \]
Compliance Model via Pneumatic Chamber

- Total compliance 1mm/mmHg
- Compliance distribution: 35% cranial, 65% spinal
Phantom Model Schematic

- Valve 1
- Valve 2
- Flow Meter
- Pulsatile Pump
- Peristaltic Pump
- CSF Production/Absorption
- Ventricles
- Brain
- Cistern
- SAS
- Reservoir
- Cspine
- Ccranial
- ICP monitoring

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Approximation of Intracranial Dynamics

ICP Peak-to-Peak: 0.8 mmHg
Approximation of Intracranial Dynamics

- **ICP (mmHg)**
  - Trajectory: Blue triangles
  - Aqueduct Pressure Drop: Red circles

- **Flow (ml/s)**
  - SAS Flow Rate: Green diamonds
  - Aqueduct Flow Rate: Red circles

**Time [s]**
Removal of Cranial Compliance

![Graph showing ICP vs time for normal and blocked cranial compliance conditions.](image)
Conclusion

- Novel phantom that approximates normal physiologic intracranial dynamics
- Modular concept allows for expansion, addition of detail or simplifications as needed

Bottan et al. (2012), *IEEE T Biomed Eng*, E-Pub ahead of print
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