Thoracic Pressure Does Not Impact CSF Pressure via Compartment Compliance

An alternative mechanism is needed to explain the impact of thoracic pressure on CSF pressure.

Thoracic Pressure Does Not Impact CSF Pressure via Compartment Compliance.

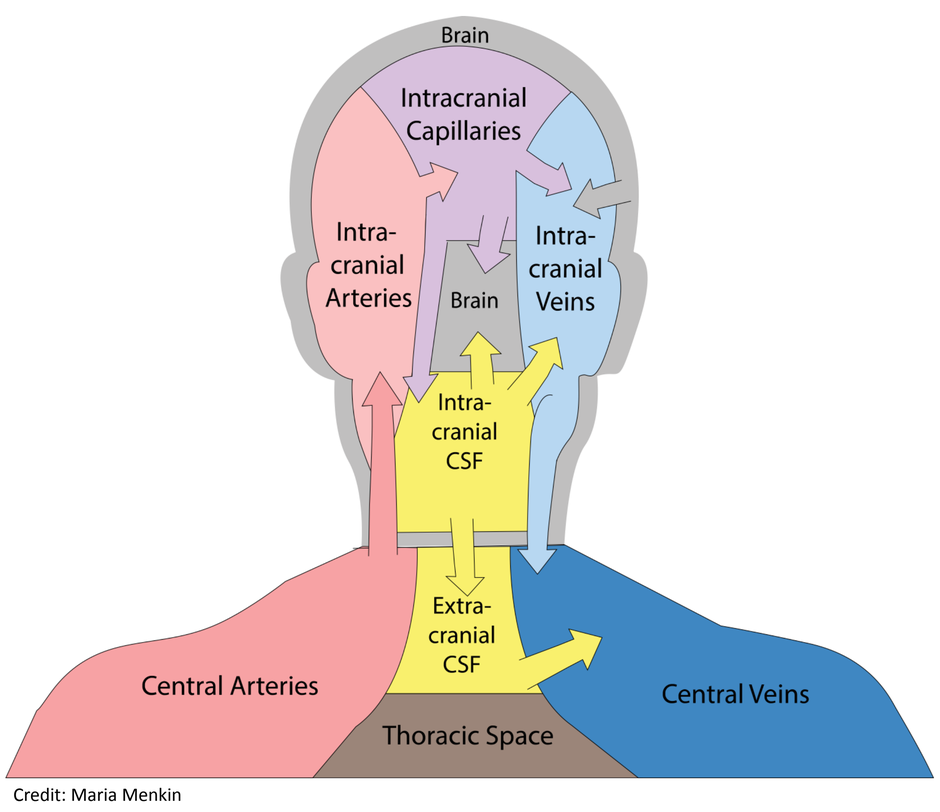
Drayton Munster, Emily Nelson, & Jerry Myers

NASA Glenn Research Center, Cleveland, OH

Introduction

- Space acquired neuro-ocular syndrome (SANS) remains a difficult risk to characterize.
- Fluid shift and the resultant change on the Cardiovascular (CV) and cerebral spinal fluid (CSF) systems in the absence of gravity continue to be considered a contributing factor to SANS.
- This study seeks to identify the impact of increased pressure in the thoracic space (due to fluid shifts) on the CSF system via compliance.

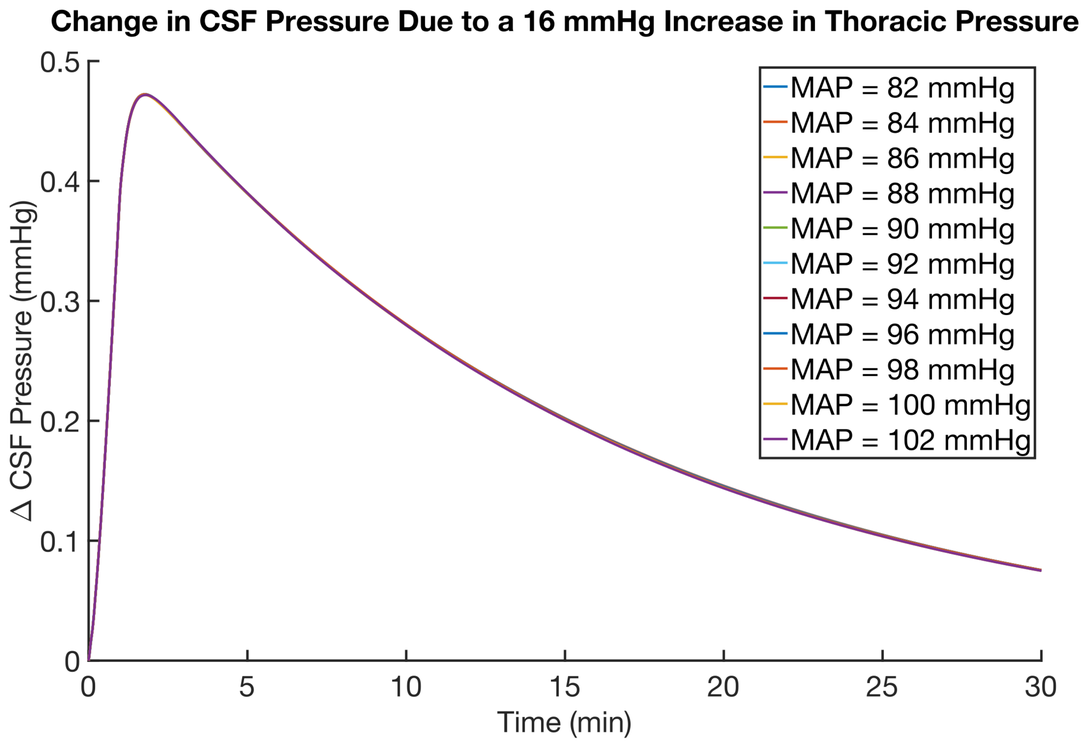
Methods



Credit: Maria Menkin

- Extension of the Stevens, et. al [1] lumped parameter model by including alternative vascular drainage pathways [2,3] and enforcing the Monroe-Kellie doctrine.
- Fixed Mean Arterial Pressure (MAP) and Central Venous Pressure (CVP), linear ramp to target Thoracic Pressure over the course of 1 minute.
- Examined Changes in Intracranial CSF Pressure and Volume over a 30-minute timescale.
- Model validated against Cerebral Perfusion Pressure (CPP) and CSF pressures measured in [4,5,6].

Results



- The change in CSF pressure that results from increasing the thoracic pressure from -6 mmHg to +10 mmHg is independent of the MAP.
- A 16 mmHg change in thoracic pressure results in a transient increase in CSF pressure by < 1 mmHg.
- Less than 1 mL of fluid shift between internal cranial compartments occurs.
- CSF Pressure is strongly tied to CPP.

Conclusions

- For a fixed MAP and CVP, the CCMP Cranial Model does not predict physiologically significant change in pressure or fluid volume for the CSF system as a result of an increase in thoracic pressure.
- Changes in CSF pressure in response to changes in thoracic pressure are more likely tied to an alternative mechanism, such as changes in CPP.

References

[1] S. A. Stevens, W. D. Lakin, and P. L. Penar, Modeling steady-state intracranial pressures in supine, head-down tilt and microgravity conditions, Aviation Space and Environmental Medicine, 76 (2005), pp. 329-338.

[2] F. Doepp, S. J. Schreiber, T. von Munster, J. Rademacher, R. Klingebiel, and J. M. Valdueza, How does the blood leave the brain? A systematic ultrasound analysis of cerebral venous drainage patterns, Neuroradiology, 46 (2004), pp. 565-570.

[3] S. J. Schreiber, F. Lurtzing, R. Gotze, F. Doepp, R. Klingebiel, and J. M. Valdueza, Extrajugular pathways of human cerebral venous blood drainage assessed by duplex ultrasound., Journal of applied physiology (Bethesda, Md. : 1985), 94 (2003), pp. 1802-5.

[4] Brimioulle, S., Moraine, J. J., Norrenberg, D., & Kahn, R. J. (1997). Effects of positioning and exercise on intracranial pressure in a neurosurgical intensive care unit. *Physical Therapy*, *77*(12), 1682–1689.

[5] Qvarlander, S., Sundström, N., Malm, J., & Eklund, A. (2013). Postural effects on intracranial pressure: modeling and clinical evaluation. *Journal of Applied Physiology*, *115*(10), 1474–1480.

[6] Eklund, A., Johannesson, G., Johansson, E., Holmlund, P., Qvarlander, S., Ambarki, K., … Malm, J. (2016). The pressure difference between eye and brain changes with posture. *Annals of Neurology*, *80*(2), 269–276.