Adult Neuroimaging: CBF/CSF, Flow/ICP

Title**: From CSF Pulsation to MR Measurement of ICP: Methodology & Potential Applications**

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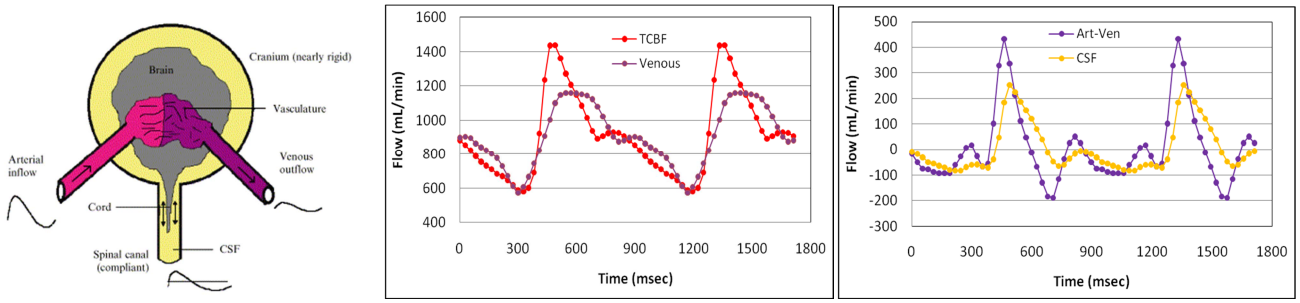
Highlights:

- Explain the origin and role of the Cranio-spinal CSF pulsation
- Describe the physiologic and fluid dynamic principles of MR-derived ICP (MRICP)
- Report recent independent validation in shunted hydrocephalic patients

Target audience: Physicians and scientists interested in craniospinal hydrodynamics

Objectives: Describe how ICP is derived from MRI of blood and CSF flows to and from the cranium.

Background: Understanding the origin of CSF pulsation and identifying factors that modulate the magnitude and shape of CSF flow are prerequisites for successful utilization of CSF flow studies in clinical practice. CSF flow is a superposition of two separate processes, a) the circulation of the CSF from its formation sites to its absorption sites (i.e., bulk flow), and b) an oscillatory (back and forth) flow during the cardiac cycle (pulsatile flow). The first process governs the overall volume of CSF in the craniospinal space and thereby influences intracranial pressure (ICP). The second process, the oscillatory movement of the CSF within the craniospinal compartments, is caused by the pulsatile blood flow entering and leaving the intracranial compartment during the cardiac cycle. These two processes occur over different time scales.CSF circulation occurs over minutes while the time scale of the pulsatile CSF flow is milliseconds (1). MRI measurements of volumetric flows to and from the cranium provided early insight into the origin of the CSF pulsation between the cranium and the spinal canal (2).



The cranio-spinal view of the origin of the CSF pulsation (left). Two cardiac cycles of MRI derived arterial inflow (TCBF) and venous outflow (middle graph). The momentary difference between inflow and outflow (Art-Ven) waveform and the CSF (yellow) pulsation (right graph). Note how the three peaks of the CSF waveform match the peaks of the A-V waveform, i.e., the driving force for the craniospinal CSF pulsation. Intracranial compliance reduces CSF pulsation with respect to its driving force (2).

Compliance and MRICP: Compliance is defined as the ratio of volume and pressure changes (dV/dP). A compliant compartment accommodates a large increase in volume with only a small increase in pressure. During systole, arterial inflow exceeds venous outflow. Due to the small cranial compliance, CSF flows from the cranium to the spinal canal to "help" accommodate the increase in intracranial volume. The intracranial pressure is exponentially related to intracranial volume. Therefore, ICP is linearly related to elastance (the inverse of compliance). MRICP derives the intracranial compliance from measurements of the volume and pressure changes occurring with every heart beat using blood and CSF flow imaging (3).

Potential Clinical Applications: MRICP is a diagnostic test, analogous to a noninvasive measurement of blood pressure. Therefore, its clinical role is different than invasive ICP monitoring. Early experience suggests that MRI measurements of compliance and ICP may enhance diagnosis and/or treatment decisions in Chiari Malformations type I (4), adult and pediatric hydrocephalous (5, 6), and mild traumatic brain injury.

References

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