Cerebrospinal fluid velocity measurement

Phase contrast magnetic resonance imaging, PC MRI, is a valuable tool allowing for non-invasive quantification of CSF dynamics, but has lacked adoption in clinical practice for Chiari malformation diagnostics. To improve these diagnostic practices, a better understanding of PC MRI-based measurement agreement, repeatability, and reproducibility of CSF dynamics is needed.

An anatomically realistic in vitro subject-specific model of a Chiari malformation patient was scanned three times at five different scanning centers using 2D PC MRI and 4D Flow techniques to quantify intra-scanner repeatability, inter-scanner reproducibility, and agreement between imaging modalities. Peak systolic CSF velocities were measured at nine axial planes using 2D PC MRI, which were then compared to 4D Flow peak systolic velocity measurements extracted at those exact axial positions along with the model.

Comparison of measurement results showed a good overall agreement of CSF velocity detection between 2D PC MRI and 4D Flow ($p = 0.86$), fair intra-scanner repeatability (confidence intervals ± 1.5 cm/s), and poor inter-scanner reproducibility. On average, 4D Flow measurements had a larger variability than 2D PC MRI measurements (standard deviations 1.83 and 1.04 cm/s, respectively).

Agreement, repeatability, and reproducibility of 2D PC MRI and 4D Flow detection of peak CSF velocities was quantified using a patient-specific in vitro model of Chiari malformation. In combination, the greatest factor leading to measurement inconsistency was determined to be a lack of reproducibility between different MRI centers. Overall, these findings may help lead to a better understanding of the application of 2D PC MRI and 4D Flow techniques as diagnostic tools for CSF dynamics quantification in Chiari malformation and related diseases [1)]

1)
Williams G, Thyagaraj S, Fu A, Oshinski J, Giese D, Bunck AC, Fornari E, Santini F, Luciano M, Loth F, Martin BA. In vitro evaluation of cerebrospinal fluid velocity measurement in type I Chiari malformation: repeatability, reproducibility, and agreement using 2D phase contrast and 4D flow MRI. Fluids Barriers CNS. 2021 Mar 18;18(1):12. doi: 10.1186/s12987-021-00246-3. PMID: 33736664.

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