

Cerebrospinal Fluid Flow Impedance is Elevated in Chiari Type 1

Nicholas Shaffer, Alaaddin Ibrahimy, Bryn Martin, Brandon Rocque, Casey Madura, Oliver Wieben, Bermans Iskandar, Stephen Dombrowski, Mark Luciano, John Oshinski, Francis Loth

Purpose

Diagnosis of Type I Chiari malformation (CMI) is difficult because the most commonly used diagnostic criterion, cerebellar tonsillar herniation (CTH) greater than 3–5mm past the foramen magnum, has been found to have little correlation with patient symptom severity. Thus, there is a need to identify new objective measurement(s) to help quantify CMI severity. This study investigated longitudinal impedance (LI) which is a parameter to assess CMI in terms of impedance to cerebrospinal fluid motion near the craniovertebral junction.

Methods

LI was assessed in CMI patients (N=15) and age-matched healthy controls (N=8) using computational fluid dynamics based on subject-specific magnetic resonance imaging (MRI) measurements of the cervical spinal subarachnoid space. In addition, cerebellar tonsillar herniation was measured for each subject.

Results

Mean LI in the CMI group ($551 \pm 66 \text{ dyn/cm}^5$) was significantly higher than in controls ($220 \pm 17 \text{ dyn/cm}^5$, $p < 0.001$). Mean cerebellar tonsillar herniation in the CMI group was $9.0 \pm 1.1\text{mm}$ compared to $-0.4 \pm 0.5\text{mm}$ in controls. Regression analysis of LI versus CTH found a weak relationship ($R^2=0.46$, $p < 0.001$), demonstrating that CTH was not a good indicator of the impedance to CSF motion caused by cerebellar herniation.

Conclusions

Diagnosis and treatment of CMI patients may benefit from an assessment of their subject-specific biomechanical environment. This work investigates the use of LI as a biomechanical parameter to assess the extent of CVJ stenosis in CMI patients. LI was found to be significantly higher in CMI patients compared to controls. LI and CTH were found to have a weakly linear relationship, suggesting that different morphometric measurements and/or biomechanical parameters may be necessary to characterize the pathoanatomy of CMI.

(a) Midsagittal MRI image for an (a) asymptomatic CMI patient and (b) symptomatic CMI patient and (c and d) 3D models for each, respectively. CTH was similar for the two cases. However, LI in the symptomatic patient was 4.2 times greater than the asymptomatic patient.



