The Interrelation of Cerebrospinal Fluid Pulse Wave Velocity and Biomechanical Properties of the Spinal Canal

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Introduction: Non-invasive assessment of the biomechanical properties of the spinal canal (SC) is of interest as a tool for diagnosis and monitoring of various craniospinal disorders including Chiari I malformation, syringomyelia, hydrocephalus and spina bifida. Abnormal spinal canal compliance has been thought to precede and/or accompany pathologies of the cerebrospinal fluid (CSF) system. While the relationship between compliance and pulse wave velocity (PWV) in the vasculature has been established, it has not been examined in the SC. Thus, examination of the relationship between CSF PWV and biomechanical properties of the SC, including lumped SC compliance, is needed.

Methods: CSF velocity wave speed in the SC was determined for three healthy volunteers using a novel cine MR sequence (Fig. 1, a. and b.) [1]. Eight simplified compliant in vitro models of the healthy SC were constructed having various elastic properties, but identical subarachnoid space geometry [2]. Pressure measurements were conducted to determine PWV on each of these models (Fig. 1, c.). A computational model was developed incorporating the in vitro SC properties and also used to determine PWV in the SC.

Results: In vivo, in vitro, and computational model PWV measurements were similar. Experimentally measured PWV compared well to the predicted PWV for all of the systems, though there was some uncertainty in terms of the relative contributions of the different theoretically-predicted wave types in the experimental measurement.

Conclusions: The presented in vivo, in vitro, and computational modeling provides a data set for future development of more accurate methodologies for non-invasive assessment of SC compliance. Further validation is needed before such PWV measurements can be used to accurately estimate SA mechanical properties.

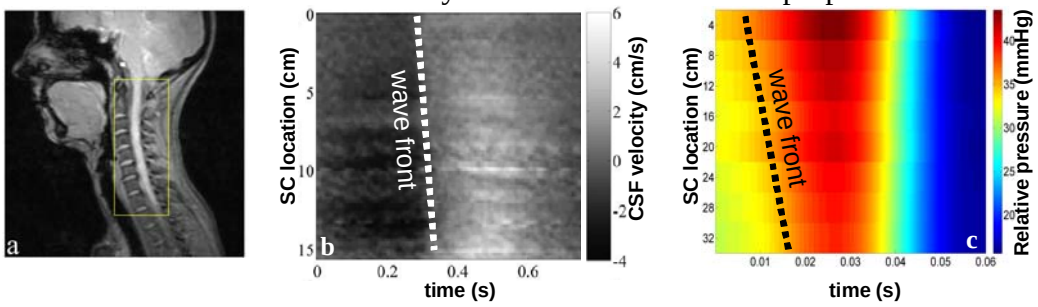

Fig. 1. a) MR of patient spinal canal (yellow box depicts ROI) [1], b) Spatial versus temporal plot of the sagittal in-plane CSF velocity wave front measured from ROI in healthy volunteer, and c) Spatial versus temporal plot of CSF pressure wave front measured in a compliant in vitro CSF model.

[1] Kalata, W., Martin, B., Oshinski, J., Jerosch-Herold, M., Royston, T., and Loth, F., 2009, "Mr Measurement of Cerebrospinal Fluid Velocity Wave Speed in the Spinal Canal," IEEE Trans Biomed Eng, pp.

[2] Martin, B. A., Kalata, W., Loth, F., Royston, T. J., and Oshinski, J. N., 2005, "Syringomyelia Hydrodynamics: An in Vitro Study Based on in Vivo Measurements," J Biomech Eng, 127(7), pp. 1110-20.