Arachnoid Trabeculae Act to Dampen the CSF Pulsation in the Spine

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Importance for Chiari patients

This project will provide new information about how the arachnoid trabeculae (AT) impact the CSF pulsation in spinal subarachnoid space. This information could help neurosurgeons further understand the importance of AT and lead towards minimally invasive surgical techniques for Chiari that target the AT.

Abstract

Two flexible spine models were constructed to simulate the movement of CSF in the spinal subarachnoid space (SSS). One model was made with arachnoid trabeculae (AT) and the other without (NO-AT). Cotton fibers were used to simulate the AT. CSF pulsations were supplied by a computer controlled pump that was programmed to produce a realistic a CSF waveform. Pressure transducers located along the model recorded unsteady pressure. The presence of AT made the CSF pressure wave 1) dampen to a much greater degree and 2) have a smaller level of wave reflection at the end of the spine. These results support that the AT could have a important impact on CSF dynamics in Chiari patients.

Introduction

The presence of AT within the SSS is well documented and a typical finding in Chiari patients. During surgery it is a common practice to remove these fibers from the tonsils to help open up the CSF space. However, the affect of AT on the CSF pulsation is not well understood. It is known that the AT have a diameter of approximately 30 mm and thus they are relatively small in size and not possible to detect by MRI. To date, computer simulations of CSF movement generally neglect the AT. The aim of this project is to build two models of the spine; one with AT and the other without and test each model to understand how the CSF pressure distribution is altered. We hypothesize that the AT will have an impact on CSF pressure distribution along the spine.

Methods

Two models of the SSS were constructed (AT and NO-AT) from a flexible polymer with properties similar to the spine (Figure 1, left and center). Cotton fibers were used to represent AT in one of the models (Figure 1, left). The structure and size of the AT fibers were documented by an Olympus IX81 inverted microscope at magnification of 40x. Both models were connected to a computer controlled pump to input a CSF pulse. Pressure transducers were positioned within each model at 9 cm intervals. Pressure signals were recorded in LABVIEW and post-processed in MATLAB software.

Figure 1. Degassing polymer to remove air bubbles before casting process (left). PVC and copper casting mold to make compliant polymer tubes (center). Microscope image of experimental AT fibers at 40x magnification (right).

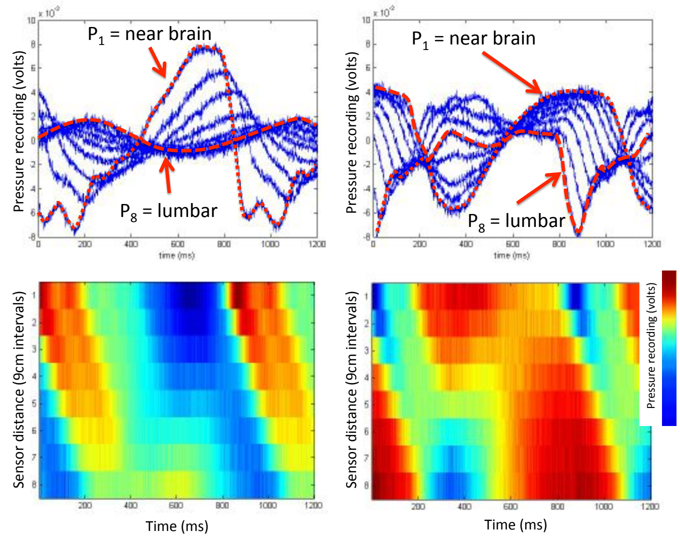

Figure 2. Pressure measurements recorded with AT (left column) and without AT (right column). Top row is the unprocessed pressure recordings. Bottom row is the temporal-spatial distribution of pressure along the spine model (y-axis represents distance along the spine, x-axis represents time, color represents pressure recording (red = higher pressure, blue = lower pressure).

Results and Discussion

Preliminary results showed that the AT act to dampen PWV as the CSF moves down the spine. In comparison to the NO-AT model, the presence of AT caused the CSF pressure wave dampen to a much greater degree and have smaller level of wave reflections at the end of the spine. This information may give a deeper understanding how specific microscopic anatomical structures influence CSF flow in the SSS. In some cases AT are removed from the CSF space near the cerebellar tonsils in Chiari surgery. Our preliminary findings indicate that AT have a very important impact on CSF dynamics that has been underestimated in the past.

Limitations

Our current physical models are limited to relatively simple components that do not include the full anatomical complexity of in vivo. Improvements in the materials used should be explored and more measurements need to be taken to fully understand the role of AT in CSF dynamics.

Conclusions

- A model of the spine including AT was successfully constructed.
- The AT were found to dampen the CSF pressure wave along the spine and reduce CSF wave reflections.
- The physiological significance of AT could be greatly underestimated in CSF dynamics related disorders.

References

1. Kalata, W., B. A. Martin, et al. (2009). "MR measurement of cerebrospinal fluid velocity wave speed in the spinal canal." IEEE Trans Biomed Eng 56(6): 1765-1768.