CHARACTERIZATION OF PRESSURE WAVE TRANSMISSION IN A FLUID FILLED SYRINX

Bryn A. Martin, B.S.
Francis Loth, Ph.D.
University of Illinois at Chicago (Chicago, Illinois)
Department of Mechanical and Industrial Engineering

John Oshinski, PhD.
Emory University (Atlanta, Georgia)
Department of Radiology

ABSTRACT
Much interest has been taken in the examination of hydrodynamic conditions of the cerebrospinal fluid (CSF) in the subarachnoid spaces (SAS) that result in the pathogenesis of Syringomyelia. Research primarily falls under one of two categories, the first being computational fluid dynamic simulation and the other being theory based on clinical observation. These studies have broadened understanding of the elusive origins of Syringomyelia. However, few studies have been empirically validated by comparison to the actual mechanical forces that occur during the pulsation of the CSF throughout the SAS. This is primarily due to the fact that taking in-vivo measurements is a highly invasive procedure that requires much risk to the patient.

Recent progress in the development and use of biomaterials has enabled researchers to build in-vitro simulations of biological flow systems. These models have enabled researchers to acquire otherwise dangerous un-obtainable invasive pressure and flow measurements that occur in biological flows. These measurements are not empirical, but can be used to broaden understanding of Syringomyelia and validate/compare with computer simulations and clinical observation.

This paper outlines the development and testing of a complete model of the cerebrospinal fluid system with a compliant fluid filled syrinx present analogous to the pathological CSF system with Syringomyelia. The model is subjected to a number of CSF flow conditions through use of a computer controlled flow pump. These flow conditions are derived from phase contrast MRI (PCMRI) measurements. A number of pressure transducers are mounted along the length of the model to measure pressures in the SAS and within the fluid filled syrinx. Pressure measurements are taken while subjecting the model to a number of PCMRI derived flow waveforms. Internal and external wave transit time measurements are obtained. The surface velocity of the syrinx is measured through laser Doppler vibrometry (LDV). The model geometry and flow waveform is obtained through MRI. MRI results are compared to experimental data derived from pressure measurements and LDV tests.

MRI Results indicate that the compliance of the spinal cord is nearly zero. LDV data indicates that syrinx wall velocity is dependant on a number of factors including syrinx tension, preloaded pressure differential and flow waveform input. Wave transit time was greater outside the syrinx than within. Different CSF flow waveforms produced varying degrees of differential pressure distribution along the spinal cord. The MRI data validates the CSF system model in that the in-vitro flow waveform accurately simulates in-vivo flow.