Two Different Techniques Analyze Chiari Related CSF Pressure

March 20, 2006 -- The cerebrospinal fluid (CSF) system is a central player in the Chiari drama. A Chiari malformation blocks the natural flow of CSF - which is driven by the heartbeat - between the skull and spine. This leads to not only abnormal CSF dynamics, such as elevated velocity and pressure, but to Chiari related symptoms and, in some people, the development of a syrinx as well.

Because of this, doctors look at CSF flow, using cine MRI, to help diagnose Chiari, monitor its progression and evaluate the results of treatment. While cine MRI can provide some data on the CSF system, because it is completely contained inside the body, the dynamics of the CSF system can be difficult to analyze for research purposes. Two recent studies, from two different research groups, have used innovative approaches to studying the CSF system in order to further our understanding of the relationship between Chiari, CSF, and syringomyelia.

In the first study, published in the February, 2006 issue of the Journal of American Neuroradiology, a group from the University of Wisconsin (Turk, Iskandar, Haughton, Consigny) used a pressure sensing transducer and a catheter to analyze CSF pressure at the foramen magnum in four dogs. A transducer is a device which converts one form of energy into another. In this case, the transducer converts the pressure it feels from the CSF into an electrical signal which can then be recorded and reflects the actual pressure in the CSF. The specific transducer used by the Wisconsin team has been widely used to measure pressure in veins and arteries and has been shown to be nearly 100% accurate.

For their experiment, the team inserted a catheter into the subarachnoid space of each dog and threaded it up to a level just below the foramen magnum. The catheter - which is a thin tube - was then used to guide a wire, with the transducer at its tip, to the same level. Finally, another catheter was inserted with an inflatable balloon at its end and placed at the level of the foramen magnum. It should be noted that the animals were anesthetized and monitored during the procedure and suffered no adverse effects from it.

The researchers were able to take CSF pressure measurements and found, much as they expected, that while the CSF pressure varied during each cardiac cycle, it was essentially the same from one cycle to the next. In other words the pressure varied within a small, well-defined range during each heartbeat. However, when the balloon was inflated to simulate the blockage of a Chiari malformation, the CSF pressure increased significantly. When the balloon was deflated, which restored normal CSF flow, the pressure returned quickly to the normal range.

The Wisconsin team feels that the value of their work lies not in the actual data they collected, but rather with the potential applications for the technique they demonstrated. They believe the same approach can be used during decompression surgery to monitor the effect of each stage (craniectomy, opening the dura, etc.) on the CSF pressure and help guide the surgery. Similarly, the technique could potentially be used in humans to analyze the pressure dynamics associated with Chiari and syringomyelia to further investigate issues such as symptom onset, progression, and syrinx formation.

In the second study, published in the December, 2005 issue of the Journal of Biomechanical Engineering, a team from the University of Illinois-Chicago and Emory University (Martin, Kalata, Loth, Royston, Oshinski) took a different approach to studying the pressure dynamics associated with a syrinx.

The mechanisms underlying syrinx formation are not completely understood, but one leading theory, known as the piston theory, holds that with each heartbeat the cerebellar tonsils are driven down into the spinal area like a piston. This in turn creates a pressure wave in the CSF which then drives fluid into the spinal tissue itself, creating a syrinx.

Critics of this theory have pointed out that since a syrinx cavity tends to expand over time (like a balloon) and push the spinal tissue out into the CSF space, the pressure inside the syrinx must be higher than the pressure of the CSF outside the syrinx in the SAS. One way to think of this is that you can't blow up a balloon by forcing air into it from the outside; you blow it up by putting air inside of the balloon which exerts pressure on the balloon and expands it. However, for the piston theory to be true, and for CSF to be forced into the syrinx from the outside, the pressure inside the syrinx must be less than the pressure outside of the syrinx.

Based on the detailed MRI analysis of a volunteer with Chiari and syringomyelia, the Chicago team built a physical model - also known as an in vitro model - to simulate and analyze pressure and movement in the subarachnoid space (SAS) and the syrinx cavity itself. The syrinx, subarchnoid space, and CSF were represented using co-axial, water filled, elastic tubes. A computer controlled pump was used to simulate the CSF motion as measured in the volunteer (see Figure 1, below).

Key Points

1. The cerebrospinal fluid system (CSF) plays a critical role in Chiari and syringomyelia
2. While cine MRI is used clinically to help make diagnoses, studying the CSF system can be difficult
3. Two new studies developed innovative approaches to studying CSF in Chiari/SM
4. First study used a catheter to place a pressure transducer into the SAS of 4 dogs at the level of the foramen magnum; a balloon was inflated to simulate Chiari
5. Found that CSF pressure increased significantly when the balloon was inflated; this technique has potential to be used during decompression surgery and to further study CSF pressure in people
6. Second study built a physical model of the SAS and a syrinx based on the MRI of a patient
7. Model was used to measure pressure and spinal wall movement
8. Found that for a period of time the pressure inside the syrinx is lower than outside, allowing for CSF to be driven into the syrinx
9. Both approaches have future potential

Definitions

cardiac cycle - one heartbeat

catheter - a thin flexible tube which can be inserted into the body and guided to a specific location; usually used to insert or remove things from the body

foramen magnum - opening at the base of the skull where the spine comes in

in vitro - in an artificial environment

in vivo - in the body

pressure - the amount of force applied to a specific surface area

subarachnoid space (SAS) - enclosed space through which CSF circulates

transducer - type of device which can convert one type of energy into another; can be used for sensing

cerebellar tonsils - portion of the cerebellum located at the bottom, so named because of their shape

cerebellum - part of the brain located at the bottom of the skull, near the opening to the spinal area; important for muscle control, movement, and balance

cerebrospinal fluid (CSF) - clear liquid in the brain and spinal cord, acts as a shock absorber

Chiari malformation I - condition where the cerebellar tonsils are displaced out of the skull area into the spinal area, causing compression of brain tissue and disruption of CSF flow

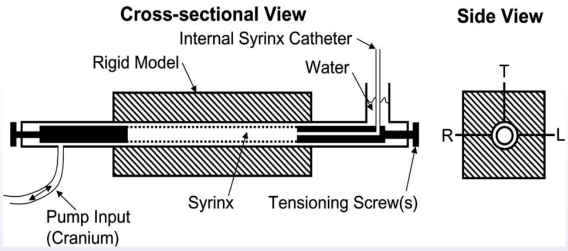
syringomyelia (SM) - neurological condition where a fluid filled cyst forms in the spinal cord

Source

Martin BA, Kalata W, Loth F, Royston TJ, Oshinski JN. Syringomyelia hydrodynamics: an in vitro study based on in vivo measurements. J Biomech Eng. 2005 Dec;127(7):1110-20.

Turk A, Iskandar BJ, Haughton V, Consigny D. Recording CSF pressure with a transducer-tipped wire in an animal model of Chiari I. AJNR Am J Neuroradiol. 2006 Feb;27(2):354-5.

Figure1: In Vitro Model Of Syringomyelia



To make sure the model accurately represented the human body, the entire apparatus was placed into the same MRI which was used on the volunteer and the CSF velocity was matched accordingly.

Once it was calibrated, pressure transducers were placed at four different locations both inside the syrinx and outside the syrinx in the SAS space. In addition, a special laser tool was used to measure the movement of the syrinx wall at several locations.

While the detailed, technical results of this experiment are beyond the scope of this publication, the researchers did find that for a period of time during each simulated cardiac cycle, the pressure inside the syrinx was less than the pressure outside the syrinx. This period of time would allow for CSF to be driven into the spinal cord to form and expand a syrinx.

Interestingly, the team also was able to record small movements of the simulated syrinx wall which were too small to be picked up by an MRI. One has to wonder if repeated vibrations of the spinal wall can lead to a weakening of the tissue and facilitate the growth of a syrinx.

While neither of these studies are likely to have an immediate impact on patients, they both represent exciting new avenues of research which may yield results for years to come.

[Ed. Note: Dr. Frank Loth and Dr. John Oshinski, cited above, are both Scientific Advisors to the C&S Patient Education Foundation, the publisher of Chiari & Syringomyelia News.]

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