Presenters

Dr. Terry Lichtor,
Neurosurgeon, Rush Presby

Dr. Noam Alperin,
Radiology, UIC

Dr. Victor Haughton,
Radiology, U of Wisconsin

Dr. Frank Loth,
Bioengineer, UIC

Dr. John Oshinski,
Radiology, Emory University

Dr. Chris Bertram,
Engineer, UNSW

Dr. Peter Carpenter,
Engineer, U of Warwick

Symposium Update: Bring On The Bioengineers

July 31, 2007 -- A funny thing happened on the way to the 2007 Conquer Chiari Research Symposium; engineers decided to show up and they brought with them a new and exciting perspective on Chiari, syringomyelia, and CSF flow. Chiari research has long been the sole domain of neurosurgeons, but in the past few years a cottage industry has sprouted up of engineers, radiologists and medical physicists using an array of advanced MRI and computational techniques to quantitatively examine CSF flow and other biomechanical properties in Chiari patients.

The Research Symposium brought together an impressive group and demonstrated both the progress they have made and the creative ideas they have for the future. Perhaps most exciting is that a number of possible candidates for an objective, quantifiable measure of Chiari are beginning to emerge. The development of a simple test which can be used to identify who has symptomatic Chiari and whether surgery was successful is one of Conquer Chiari's top research priorities.

Below is a brief description of the some of the presentations in this area:

Compliance

Early in the morning, Drs. Noam Alperin and Terry Lichtor generated quite a bit of buzz with their presentation on using advanced MRI techniques to measure compliance and its role in Chiari.
As discussed in Compliance May Be Key To SM & Alzheimer's, compliance is a measure of a vessel's, or container's, stiffness. It is measured as the change in volume of a vessel in response to a change in pressure. A highly compliant container, like a balloon, can be expanded by blowing air into it. A low compliance container, like a glass jar, will not expand much as the pressure inside it is increased.

Recall that with every heartbeat, blood rushes into the brain/cranium via arteries, blood flows out through veins, and CSF flows from the skull to the spinal area. Thus, intracranial compliance is a measure of how the cranium/brain area responds to the inrush of blood during a heartbeat.

To measure compliance, the research team quantifies the total amount of blood and CSF flowing into and out of the skull area during a heartbeat, quantify the pressure of the CSF, and then mathematically derive a Compliance Index.

However, Alperin and Lichtor have gone well beyond just developing a technique to measure compliance, they have demonstrated (and published) that the Compliance Index tends to be lower than average in Chiari patients, and also that decompression surgery increases the Compliance Index of Chiari patients.

In one study, they scanned and calculated the Compliance Index of 34 Chiari patients and compared the results to 17 healthy controls. The Chicago team found that the Compliance Index for the Chiari group was on average 20% lower than the healthy controls (6.7 vs 8.3).

In a second study, the researchers measured the Compliance Index, both before and after surgery, for 12 Chiari patients. Here they found that the compliance increased an average of 64% after surgery. Individually the compliance increased in 10 out of the 12 patients, remained unchanged in one, and actually decreased in another. Interestingly, the person in whom compliance decreased after surgery was the one person who continued to suffer from symptoms after surgery.

One of the neurosurgeons in the audience asked the obvious question, namely do Alperin and Lichtor foresee developing a cut-off point below which indicates Chiari (in other words an objective, numerical test for Chiari). The presenters responded that that is their goal. Perhaps the best news is that they successfully secured a large NIH grant to do just that.

CSF Flow Patterns

While compliance shows promise in terms of an objective Chiari test, it is by no means the only possibility for such a test. Another group that has been exploring this area is from the University of Wisconsin. There, Drs. Haughton, Iskandar, and others have been developing advanced techniques to look at CSF flow and velocity patterns in Chiari patients.

They have published several papers showing that Chiari patients tend to have high speed CSF jets around the cerebellar tonsils and to exhibit abnormal flow patterns, such as CSF flowing in two directions at once.

The researchers believe they can link specific CSF patterns to symptoms and in that way create an objective measure of Chiari symptoms.

Longitudinal Impedance

Frank Loth, a bioengineer at UIC and one of the symposium organizers presented another candidate for a quantitative measure of Chiari. Loth's technique uses a detailed MRI map of an individual's anatomy and then uses computational fluid dynamics to calculate the Longitudinal Impedance (LI) to CSF flow for that specific person.

Basically, LI is a measure of the global resistance to CSF flow exiting the skull due to the reduced area in the spinal canal where the cerebellar tonsils have herniated. Another way to think about LI is that it represents the resistance to the unsteady, or pulsatile, flow of CSF.

Loth and his team have computed this resistance parameter on two patients before and after surgery as well as on one healthy subject. The LI magnitude for the healthy subject was a relatively low (meaning not much resistance to CSF flow) 148. This compared to an LI of 435 and 330 for the two Chiari patients; a significant difference in the resistance to CSF. In addition, both Chiari patients demonstrated a significant drop in LI after decompression surgery - 31% and 21% respectively - although not to the level of the healthy subject.

Although the calculation has only been run on a small number of patients, Loth is planning on doing a larger study in the future and also plans on refining the currently computer intensive technique so that it can be performed much more quickly. The end goal is to have a system which can accurately model an individual's spinal geometry and calculate parameters such as LI. One can also imagine how such a system could be used to model the effects of surgery and help guide surgeons in how much bone to remove to achieve optimal results.

Pulse Wave Velocity

Since the flow of CSF is driven by the beating of the heart, it is pulsatile in nature, meaning that it pulses down the spinal cord. In heart disease research, studying the velocity of the pulse wave of blood in an artery can reveal whether the artery is stiff and abnormal, or healthy.

Dr. John Oshinksi, of Emory University, thinks that measuring the pulse wave velocity (PWV) of CSF in the spinal cord can similarly reveal the degree to which the flow of CSF is abnormal due to a Chiari malformation. Mathematically, the pulse wave velocity is an indication of the stiffness (or compliance) of the system, and compliance has already been shown to be clinically relevant. The PWV can also be an indication of the peak intracranial pressure, which also may play an important role in Chiari related symptoms.

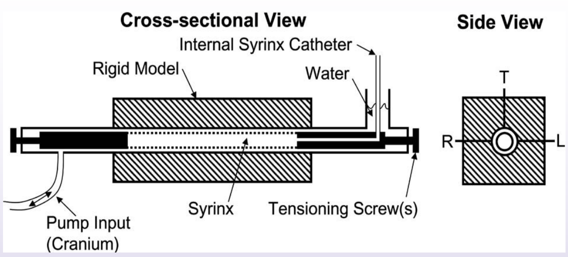
To date, the PWV of CSF has not been measured, but Dr. Oshinski has developed a cutting-edge technique to do just that using MRI. This advanced work is in the early stages, but shows promise as an additional biological parameter that may be important in Chiari and syringomyelia patients.

Physical Model

During the breaks throughout the day, in addition to discussing the presentations, symposium attendees were given the opportunity to view a demonstration of a physical model of the pressures involved in a syrinx cavity.

Based on the detailed MRI analysis of a volunteer with Chiari and syringomyelia, Bryn Martin (one of Dr. Loth's students) built a physical model - also known as an in vitro model - to simulate and analyze pressure and movement in the subarachnoid space (SAS) and a 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).

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 (devices for measuring pressure) 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.

The model, which generated a good deal of interest and is part of Bryn's PhD work and has already resulted in one journal publication, should enable a detailed look at the environment around which syrinxes form.

Beyond Chiari

The bioengineers are working on a broad variety of research areas, including ones related to, but beyond Chiari. Specifically, Dr. Bertram traveled from Australia to present his computational model of how scarring after spinal trauma can lead to the formation of a syrinx. Questioned hard by the neurosurgeons in the room, Bertram's impressive computer simulations showed how scar tissue can pull at the spinal tissue it is attached to and allow for fluid to enter the spinal cord.

Summary

Overall, the symposium had a good balance of technical researchers and practicing clinicians. The interchange between the groups was lively, insightful, and very promising for the future of Chiari research.
