Computer Analysis Examines Post-Traumatic Syringomyelia

April 20, 2006 -- Historically, research into Chiari and syringomyelia has largely been limited to neurosurgeons and neurologists. Recently however, a new type of researcher, specifically biomedical engineers, have begun to turn their attention to the complexities of these conditions.

Biomedical engineering can be defined as the application of engineering principles, techniques, and processes to biological and medical problems. Biomedical engineers develop devices such as prosthetic limbs, imaging systems, surgical devices, and artificial organs.

There are many different.htmlects to biomedical engineering, but one well established specialty area, biomechanics, is of particular relevance to Chiari and syringomyelia. Biomechanics looks at problems such as how things move and flow in the human body. For example, studying the mechanics of the heart and blood flow led to the development of the artificial heart and replacement valves.

In fact, the study of how fluids flow, also known as fluid dynamics, could be critical in furthering our knowledge and understanding of Chiari and syringomyelia. Recall that both Chiari, and especially syringomyelia, involve the flow of cerebrospinal fluid (CSF), the liquid that naturally circulates around the brain and spine, driven by the heartbeat cycle.

Chiari essentially blocks and disrupts the natural flow of CSF between the skull and spinal region, and syringomyelia is by definition a fluid-filled cyst in the spinal cord itself. While there are several theories on how syrinxes form and grow, none have been proven conclusively and the underlying mechanics remain poorly understood.

Some researchers believe, and there is some evidence to support this, that CSF flows into the spinal tissue along what are called perivascular spaces. Perivascular spaces are small spaces along the outside of the arteries and veins that supply blood to the spinal tissue. However, as this publication has highlighted in several articles, since syrinxes tend to grow over time like a balloon, it is not clear how CSF can be forced into the syrinx from the outside.

Several years ago, biomedical engineers began to study the flow of CSF, using computer modeling, to try to gain a better understanding of the effect Chiari has and why and how syrinxes form. Interestingly, the computer models showed that the pressure dynamics were just right to allow for both CSF to be forced into the spinal cord and for the syrinx to expand over time.

Recently, a group of researchers from Australia (Bilston, Fletcher, Stoodley), used a similar computer modeling technique to analyze CSF flow in post-traumatic syringomyelia. They reported their results on-line in March, 2006. in the journal Clinical Biomechanics.

Post-traumatic syringomyelia (PTS), where a syrinx forms due to a traumatic spinal cord injury, can be very difficult to treat. PTS develops in up to 25% of spinal cord injury patients and a syrinx can form many years after the initial injury. Surgery to drain the syrinx, decompress the local region, or remove scar tissue is successful only about 50% of the time and PTS can lead to a dramatic decline in quality of life for the patient.

Previous PTS research has shown that, similar to Chiari related SM, a spinal cord injury alters the local flow of CSF and may lead to a situation where CSF is driven into the spinal tissue along the perivascular spaces. It has also been noted that syrinxes tend to form in the region adjacent to arachnoiditis.

The arachnoid is the thin middle covering of the brain and spinal tissue and forms the top boundary of the subarachnoid space, through which CSF flows. The arachnoid tends to stick down, tendril-like, to the tissue beneath it (the bottom boundary of the subarachnoid space), and if these connections become too thick or scarred, they can form adhesions which can disrupt the flow of CSF.

The Australian researchers decided to analyze the effect that arachnoiditis scarring has on CSF pressure around the scarred region. To accomplish this, they built a computer based, mathematical, two-dimensional model of the spinal geometry based on the MRI of an actual PTS patient (see Figure 1). They simulated the CSF flow based on previous research of flow dynamics using cine-MRI and the arachnoid scarring was modeled as a porous substance (or one that allows the flow of a fluid through holes).

Table 1
Geometry Of Model Used With PTS Patient MRI

Key Points

1. Recently researchers have begun to use computer modeling to study how syrinxes form
2. This study created a computer analysis to examine post-traumatic syringomyelia
3. PTS can occur in up to 25% of spinal cord injuries and can develop years after the initial trauma
4. Computer model showed that the amount of arachnoid scarring may have a large influence on the pressure of CSF above the injury
5. This in turn might drive CSF into the spine through the perivascular spaces
6. This computer model was fairly simple, but future work should produce more realistic simulations and possibly provide greater insights

Definitions

arachnoid - thin, middle layer of the coverings of the brain and spinal cord, lies beneath the dura

arachnoiditis - inflammation or scarring of the arachnoid

fluid dynamics - field of study which mathematically describes the properties of fluids

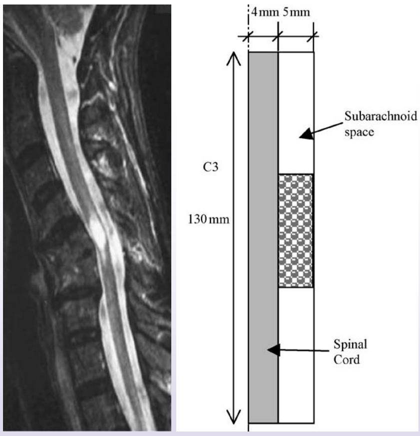
perivascular spaces - small spaces around the outside of arteries and veins

permeability - a measure of how easily a fluid can move through a porous substance

porous - describes something which has many holes, which can allow a fluid to move through it

post-traumatic syingomyelia (PTS) - type of syringomyelia which develops secondary to a traumatic spinal cord injury

subarachnoid space (SAS) - space, beneath the arachnoid, through which CSF circulates



Note: The general geometry of the computer model was based on an actual PTS patient

Since no one has really looked at the actual properties of arachnoid scarring, the research team ran a number of simulations, varying the parameters of the arachnoiditis across a range of values. They found that the pressure of the CSF above the arachnoid blockage was extremely dependent on the permeability of the scarred region. Specifically, when the region was made less permeable - or more restrictive to flow - the CSF pressure above the region increased to up to 20 times the normal value.

Similar to the modeling of Chiari related syringomyelia, this finding would appear to support the idea that syrinxes form because CSF is forced into the spinal tissue along the perivascular spaces. While this type of modeling may seem crude given the large assumptions that are required in designing the model, for now it is one of the few ways available to study syrinx formation. Since the CSF system is self-contained, it is difficult to study directly without disturbing the system and changing things.

Reading about this type of research may not be exciting for patients, but the work the biomedical engineers are doing is invaluable in laying the foundation for future understanding and progress. As their modeling techniques improve and become more realistic, their work is likely to reveal significant insights.

It is worth noting that to date, no one has modeled the effects of arachnoid scarring on Chiari related syringomyelia, yet many surgeons favor removing such scars and adhesions during decompression surgery. In addition, if further research proves that arachnoid scars contribute to syrinxes forming, it is interesting to speculate about possible future treatments. Will it be possible one day to inject a drug into a person's CSF which breaks up arachnoid scars and helps drain syrinxes, or perhaps prevents them from forming in the first place? Only time, money, and research will tell.

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New fluid flow model may shed light on post-traumatic syrinx formation

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Common Chiari Terms

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

decompression surgery - general term used for any of several surgical techniques employed to create more space around a Chiari malformation and to relieve compression

MRI - magnetic resonance imaging; large device which uses strong magnetic fields to produce images of soft tissue inside the human body

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

syrinx - fluid filled cyst in the spinal cord

Source

Bilston LE, Fletcher DF, Stoodley MA. Focal spinal arachnoiditis increases subarachnoid space pressure: A computational study. Clin Biomech (Bristol, Avon). 2006 Mar 10; [Epub ahead of print]