Key Points

1. Research has shown that the amount of tonsillar herniation (mm) is not related to symptoms or clinical outcome
2. Cine-MRI, which can show CSF flow, is becoming a more common measure
3. Not all surgeons are convinced of usefulness of cine MRI
4. Some question the value of measuring overall flow
5. Study looked at flow characteristics of specific points at specific times in 8 Chiari children, pre and post surgery, plus two healthy children
6. Found that the flow pre surgery had higher velocity peaks at certain points and often exhibited flow in two directions at the same time
7. These were not seen in the healthy subjects
8. Authors believe that more complex characteristics of CSF flow are required in evaluating Chiari

Definitions

caudal - towards the tail; in this case CSF flow from the brain to the spine

cephalad - towards the head; in this case CSF flow from the spine to the brain

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 - condition where the cerebellar tonsils are displaced out of the skull area into the spinal area, causing

CSF Flow In Children Before & After Surgery

In recent years both researchers and clinicians have turned their attention to the role that the flow of cerebrospinal fluid (CSF) plays in Chiari and syringomyelia. CSF is a clear liquid which bathes both the brain and spinal cord (under the dura, in the subarachnoid space) and acts as a shock absorber. In a healthy person, CSF flows freely from the skull area to the spinal area and back, driven by the heartbeat. More specifically, when the heart beats, blood rushes into the brain and forces CSF out and into the spine area. In the second phase of the cardiac cycle, this is reversed and CSF flows from the spine back into the brain.

When the cerebellar tonsils descend out of their natural position, past the foramen magnum and into the spinal area, their physical presence disrupts - or blocks - the natural flow of CSF. It is believed that the disrupted CSF flow is the cause of many symptoms, including syrinx formation, and one of the goals of surgery is to restore the natural flow of CSF.

The recent focus on CSF flow is in contrast to the early definition of Chiari. When MRI's were first introduced, they could produce only static, anatomical images. Using standard MRI's Chiari malformations were assessed based on the amount of tonsillar herniation below the skull. Someone with 3mm of herniation would be considered to have mild, or borderline Chiari; while someone with 1 cm or more would be considered to have a severe case. The problem with this method is that research has shown time and again that the amount of herniation is not related to either symptoms or clinical outcomes.

With this in mind - and the notion that CSF flow plays a critical role - the development of cine MRI, which is able to show CSF flow timed to the heartbeat and not just static images, appeared to offer a new way to assess Chiari cases. Indeed, cine MRI has become a routine diagnostic tool for many surgeons; however, despite it's growing popularity, some have begun to question the usefulness and value of looking at overall flow. Research studies have shown wide variations depending on how and where flow is measured and to date no single parameter, such as total flow or average velocity, has been found which strongly correlates with symptoms or surgical outcome.

In a November, 2004 supplement to the Journal of Neurosurgery, three researchers from the University of Wisconsin, Dr. Iskandar, Dr. Quigley, and Dr. Haughton, propose that using cine MRI to look at measures such as total flow are not sufficient and that more complex measures must be used to accurately characterize the Chiari state.

Iskandar and his colleagues carefully analyzed the CSF flow of 8 children with Chiari, both pre and post surgery, and 2 children without Chiari. Instead of measuring average velocity and total flow, they focused on specific characteristics at many discrete points - or voxels - around the foramen magnum at 14 different times during the cardiac cycle. At each point in space and time, they looked at four different parameters:

1. An increase in the peak CSF velocity in both the caudal and cephalad direction
2. Differences in velocities of regions close together - in other words CSF flowing at different speeds
3. CSF flowing in both directions at the same time in regions close to each other, quantified on a scale of 0-6
4. Tendency for CSF to flow more in one direction than the other

Each patient had a Chiari of at least 3mm in length and represented a range of symptom severity. They all underwent similar surgeries and were evaluated both before and several times after surgery. Seven of the eight improved after the initial surgery, but one child required a second surgery where part of a tonsil was removed.

In analyzing the results of the flow studies, the Wisconsin team found that before surgery the CSF flow of the Chiari patients was very fast in some areas and slower in others. These high speed jets, tended to disappear after surgery. In addition, in 6 of the 8 patients, the peak CSF velocity was higher before surgery than after surgery (see Table 1). The team also found in these patients that CSF would flow in both directions at the same time (see Table 2).

Perhaps most interesting to note is the fact that while these parameters decreased after surgery for most of the patients, in the one child for whom the surgery failed there was no change in the CSF characteristics. However, after the second, successful surgery, the CSF velocity and bidirectionality did decrease.

Also, in the healthy children, the CSF velocity was lower and more uniform, and there were no cases where CSF was flowing in both directions at once. Taken together, the results would indicate that Chiari malformations result in uneven, disrupted CSF flow characterized by high speed jets, uneven speed, and uneven direction of flow.

compression of brain tissue and disruption of CSF flow

cine MRI - type of MRI which can show CSF flow, also known as phase contrast MRI

craniectomy - surgical technique where part of the skull is removed

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

dura - tough, outer covering of the brain and spinal cord

duraplasty - surgical technique where the dura is opened and expanded by sewing a patch into it

flow - the amount of a fluid which moves across a space in a given amount of time; for example one milliliter per second

foramen magnum - opening at the bottom of the skull where the brain and spinal cord meet

laminectomy - surgical technique where part of a vertebra is removed

magnetic resonance imaging (MRI) - diagnostic device which uses a strong magnetic field to create images of the body's internal parts

posterior fossa - depression on the inside of the back of the skull, near the base, where the cerebellum is normally situated

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

syrinx - fluid filled cyst in the spinal cord

tonsillar herniation - descent of the cerebellar tonsils into the spinal area; often measure in mm

velocity - how far something travels in a given amount of time; for example miles per hour, or centimeters per second

voxel - a single point in an MRI image; like a pixel on a TV or computer screen

Source

Iskandar BJ, Quigley M, Haughton VM. Foramen magnum cerebrospinal fluid flow

From this, the authors conclude that more complex analysis than is generally used right now is necessary in looking at CSF flow across the foramen magnum and that quantitative parameters should be found which correlate with symptoms and clinical outcomes.

Because this research is on the cutting edge, it does have several limitations. Most notably, the small number of cases are not enough to draw strong conclusions. In addition, the team only looked at data at the foramen magnum. Finally, no attempt was made to tie the imaging findings back the symptoms of the patients. It could be that herniated tonsils can cause CSF flow disruption, without causing real problems. To rule out that possibility, the team proposes analyzing the flow characteristics of an asymptomatic Chiari patient.

Despite the early nature of this work, it is very encouraging to see imaging techniques and technology continue to progress. It will be interesting to watch where this line of research takes us in the next few years.

Table 1
Peak Velocities Of Chiari Patients, Pre and Post Op

	Cephalad (cm/s)		Caudal (cm/s)	
#	Pre	Post	Pre	Post
1	9.9	4.2	-2.3	-2.7
2	3.6	4.5	-2	-2.4
3	10.1	3.3	-5.4	-2.1
4	4.5	17.9	-3.1	-5.1
5	9.9	4.8	-5.2	-2.8
6	3	3	-2.7	-2
7	14.2	4	-4.5	-4
8	22.2	11.3	-16	-6

Table 2
Bidirectionality Score of Chiari Patients, Pre and Post Op

#	Pre	Post
1	5	4
2	5	4
3	5	2
4	6	4
5	6	4
6	4	4
7	4	2
8	6	5

Note: *Bidirectionality was quantified on a scale of 0-6*

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characteristics in children with Chiari I malformation before and after craniocervical decompression. J Neurosurg. 2004 Nov;101(2 Suppl):169-78.