## Key Points

1. In a healthy person CSF flows from the brain into the spinal area and back with every heartbeat
2. The quantitative study of CSF flow using phase-contrast MRI is fairly new and there are no agreed upon standards for analysis
3. In addition, there can be wide variation of flow patterns between individuals
4. Previous research has suggested that the blockage created by a Chiari malformation creates high speed CSF jets at the foramen magnum
5. This study showed that decompression surgery significantly reduces the maximum CSF velocity at the foramen magnum
6. However, this finding did not correlate with clinical outcome; in other words there was no link between symptom improvement and CSF velocity decrease

## Definitions

**cardiac -** relating to the heart

**caudal -** towards the tail, in the case of CSF flow, from the skull to the spine

**cephalad -** towards the head, in the case of CSF flow, from the spine to the skull

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

**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 compression of brain tissue and disruption of CSF flow

**cranial nerve -** one of 12 pairs of nerves that originates in the brain

# Decompression Surgery Reduces CSF Velocity

Anyone who's played with a garden hose in the summertime understands the concept that the water will flow out faster if you partially cover the end of the hose with your thumb. There is evidence that a similar thing happens when a Chiari malformation blocks the flow of cerebrospinal fluid (CSF), and now a group from the University of Wisconsin has shown that decompression surgery reverses that effect and can reduce the velocity of CSF as it flows around the cerebellar tonsils.

In a healthy person, CSF flows from the brain to the spinal cord and back again with every heartbeat. When the heart beats, it pumps blood into the brain. Since the skull is rigid, the increased blood in the brain creates pressure which sends CSF from the brain, through the foramen magnum, and into the spinal area (this is referred to as the caudal direction). As the heart retracts, the process is reversed and some CSF flows back into the brain (this is referred to as the cephalad direction).

With the development of phase-contrast MRI, scientists have been able to begin quantifying how CSF flows into and out of the spinal area. Unfortunately, this is not an easy process. Analyzing the data from the MRI is not straightforward and several techniques have been developed, which don't necessarily produce the same results. In addition, the flow of CSF itself appears to be very complicated and to vary from person to person. Despite these obstacles, there are early indications that like a garden hose, the tonsils of a Chiari malformation do create abnormal CSF flow and create high-speed jets that are not found in healthy people.

To build on this, Dr. Dolar (now at Indiana University) and her colleagues Dr. Haughton, Dr. Iskandar, and Dr. Quigley, examined 8 Chiari patients who underwent surgery between 1999 and 2001 and who had phase-contrast MRI studies done both before and after surgery. They used a technique they developed to measure the maximum velocity of every voxel - a 3-dimensional pixel - in the foramen magnum area 14 times during the cardiac cycle. From this, they identified the maximum velocity for each patient in both the caudal and cephalad directions. In addition, they reviewed clinical symptom data on whether the subjects suffered (before and after surgery) from:

- occipital headaches
- Valsalva (strain induced) headaches
- motor deficiencies
- sensory deficiencies
- vertigo
- cranial nerve dysfunction

The surgical technique used was similar for all patients and included a craniectomy, C1 laminectomy, and duraplasty. The group published their results in the January, 2004 issue of the American Journal of Neuroradiology.

Overall, the researchers found that the CSF velocity in the caudal direction did decrease for 6 out of the 8 patients. For the group as a whole, the average maximum velocity dropped significantly from 3.4 cm/s to 2.4 cm/s. In the cephalad direction, the maximum velocity also decreased for 6 out of 8 patients, but the decrease was more pronounced than the other direction. On average, the maximum cephalad velocity decreased from 6.9 cm/s to 3.9 cm/s, a finding that is on the verge of being statistically signficant.

Surprisingly - given the growing popularity of CSF flow studies - the researchers did not find a correlation between clinical outcome and a reduction in CSF velocity. In addition, for three patients, either one or both velocities actually increased after surgery.

Mathematically studying fluid flow is a complicated and difficult undertaking where many assumptions are often made in an attempt to get a handle on the problem. The failure of this study to find a connection between symptoms and CSF velocity may indicate that CSF analysis needs to look beyond simple velocity, or it may indicate that there really is no connection between the two.

**Selected Publications**


- Haughton VM, Korosec FR, Medow JE, Dolar MT, Iskandar BJ.**Peak systolic and diastolic CSF velocity in the foramen magnum in adult patients with Chiari I malformations and in normal control participants.** AJNR Am J Neuroradiol. 2003 Feb;24(2):169-76.
- Iskandar BJ, Hedlund GL, Grabb PA, Oakes WJ. **The resolution of syringohydromyelia without hindbrain herniation after posterior fossa decompression**. J Neurosurg. 1998 Aug;89(2):212-6.

instead of the spinal cord

**duraplasty -** surgical technique where a patch is sewn into the dura, the tough covering of the brain and spinal cord

**foramen magnum -** large opening at the base of the skull, through which the spinal cord passes and joins with the brain

**laminectomy -** surgical removal of part (the bony arch) of one or more vertebrae

**occipital -** relating to the back part of the head

**phase contrast MRI -** type of MRI which can measure the velocity of CSF

**syringomyelia -** neurological condition where a fluid filled cyst forms in the spinal cord

**Valsalva -** straining, a Valsalva headache is one brought on by straining

**velocity -** how fast something moves in a certain direction

**voxel -** the smallest distinguishable unit of volume; like a 3D pixel