# Cerebrospinal Fluid (CSF) Flow in Pediatric Patients with Type I Chiari Malformation Compared to Control Subjects

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## Purpose

Stratifying pediatric patients with Type I Chiari Malformation (CM-1) into effective treatment groups, including possible decompression surgery, remains a significant challenge. Previous studies suggest that the extent of tonsillar descent, though partially responsible for obstructing CSF flow, does not correspond to the severity of clinical symptoms or prognosis.[1,2] In the pediatric population, subjects have difficulty verbalizing symptoms, which suggests a need to develop quantitative metrics of CSF flow dynamics to characterize severity of the disease and assess response to therapy. Cardiac-gated phase contrast MR (PCMR) imaging is used to assess the hydrodynamics of CSF flow in patients with CM-1. The vast majority of studies that have examined CSF flow dynamics with PCMR have been in the adult population. Those with pediatric patients have been small in size or had combined pediatric and adult data.

The objectives of this study were: 1) to determine CSF flow parameters in pediatric subjects with CM-1, 2) to determine whether differences exist in CSF flow parameters between pediatric CM-1 patients (with and without syringomyelia) and control subjects, and 3) to compare flow parameters between pediatric subjects and adult subjects.

## Methods

Forty (40) CM-1 patients (9.7 +/- 4.8 years of age) participated in the study, all of whom were referred from a single neurosurgeon for an MRI between August 1st, 2012 and July 31st, 2014. 42.5% (17/40) of subjects presented with syringomyelia. A separate set of 8 control subjects (6.5 +/- 4.5 years of age) who underwent a clinically ordered MRI for non-specific headache symptoms, but were determined to be structurally normal by a neuroradiologist, were utilized for comparative analysis. Thus, the study consisted of three groups: CM-1 patients without syringomyelia (n=23), CM-1 patients with syringomyelia (n=17), and controls (n=8).

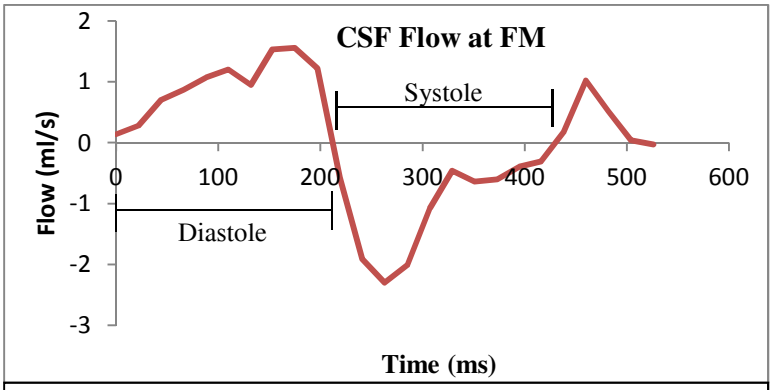


**Figure 1**. CSF flow curve showing systolic (caudal) and diastolic (cranial) flow over one cardiac cycle.

The MRI for all 48 subjects included two cardiac-gated phase contrast magnetic resonance (PCMR) scans to quantify CSF flow: 1) an axial slice using through-plane velocity encoding (VENC =15 cm/sec, 25 frames over the cardiac cycle, 1.1 x 1.1 x 5 mm voxel size) at the foramen magnum, and 2) a mid-sagittal slice using in-plane velocity encoding in the superior-inferior direction (VENC=15 cm/sec, 37 frames over the cardiac cycle, 0.8 x 0.8 x 4 mm voxel size). CSF flow parameters including total flow (absolute value integrated over the cardiac cycle, Figure 1), peak systolic (caudal) velocity, and peak diastolic (cranial) velocities were determined using FLOW software (AZL, Netherlands). T-tests were used to conduct statistical comparisons.

## Results

Maximum CSF velocity during systole and diastole over all the Chiari patients, with and without syringomyelia, averaged 7.7 +/- 3.8 cm/s and 4.8 +/- 1.5 cm/s, respectively. Similarly, maximum systolic and diastolic velocities over all the control subjects averaged 9.4 +/- 1.8 cm/s and 5.5 +/- 1.0 cm/s, respectively. The difference in magnitude between peak systolic and diastolic velocities was significant within ($p<0.01$) but not across both groups, indicating higher systolic velocities than diastolic velocities in both patients and controls.

Differences in total flow were not significant between CM-1 patients with or without syringomyelia and controls. However, CM-1 patients with syringomyelia were found to have lower peak systolic velocities on average (4.2 +/- 1.3 cm/s) than patients without a syrinx (5.3 +/-1.6 cm/s, $p=0.03$) and than controls ($p=0.02$). Patients with a syrinx also exhibited lower peak diastolic velocities (6.5 +/- 3.7 cm/s) compared to controls ($p=0.01$). The lower peak velocities may reflect a difference in compliance in subjects with syringomyelia compared to CM-1 patients without syringomyelia and structurally normal subjects.

Maximum velocities in the pediatric population are significantly higher than those reported in the adult population during systole (range of 1.2 - 3.3 cm/s) and during diastole (range of 1.6 - 4.5).[3]

## Conclusions

Peak systolic (caudal) CSF velocities are significantly higher than peak diastolic (cranial) CSF velocities in both pediatric subjects with CM-1 (1.6x) and pediatric controls (1.7x). The cranial-to-caudal difference in peak velocities and the absolute magnitude of peak caudal and cranial velocities are both significantly higher than CSF velocities reported in the adult population. Patients with syringomyelia were found to have lower peak velocities and larger phase differences during cranial flow compared to patients with Chiari and no syringomyelia and compared to controls. These findings suggest: 1) CSF flow velocities are elevated in *all* pediatric subjects compared to adults, and 2) disruptions to CSF flow patterns are only evident in the pediatric CM-1 population with syringomyelia.

## References

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2. Hofmann et al. (2000) *AJNR 21*(1), 151-158.
3. Iskandar et al. (2005) *J Neurosurg Ped 103*(6), 508-511.