CSF FLOW QUANTIFICATION IN CHIARI MALFORMATION PATIENTS

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IMPORTANCE FOR CHIARI PATIENTS

This project will provide new understanding about whether differences in CSF dynamics in patients with Type I Chiari malformation are observable and quantifiable through flow waveform analysis. Results from this work may help quantify the severity of CMI in terms of alterations to CSF dynamics.

ABSTRACT

This study investigates differences in CSF flow waveforms in patients with Type I Chiari Malformation (CMI). Flow waveforms were obtained from phase-contrast MR images of 8 CMI patients pre-surgery, 4 patients post-surgery, and 6 healthy volunteers. Waveforms were analyzed qualitatively. Peak flow rate (PQ) and stroke volume (SV) were calculated and compared statistically. Results show qualitative differences in the flow waveforms from CMI patients and healthy volunteers. SV at the C2, C6 and T2 levels of the spine were lower in CMI patients than healthy subjects.

INTRODUCTION

Changes in CSF velocity near the craniovertebral junction have long been associated with CMI. However, past studies that attempted to characterize post-surgical changes in CSF hydrodynamics have focused on qualitative analysis of velocity fields and yielded mixed results. To our knowledge, post-surgical changes in CSF flow waveforms in the cervical spine have not been analyzed. The goal of this study was to qualitatively and quantitatively investigate post-surgical changes in CSF flow waveforms in CMI patients at the FM, C2, C6, and T2 levels of the spine.

METHODS

Eight CMI patients volunteered to be imaged for this study. All had cerebellar herniation ≥5 mm beyond the FM and sufficient neurological symptoms to warrant corrective surgery. Four of the patients have been imaged post-surgery. Patients were compared with a group of six healthy volunteers with no history of neurological disorder or spinal trauma. A peripheral pulse-gated pcMR imaging sequence was used to acquire velocity images at the FM, C2, C6, and T2 levels of the spine. Velocity images were segmented using a custom MATLAB interface (Figure 1) and flow waveforms at each level were computed from the resulting segmentation. PQ and SV were computed from the waveforms and compared statistically.
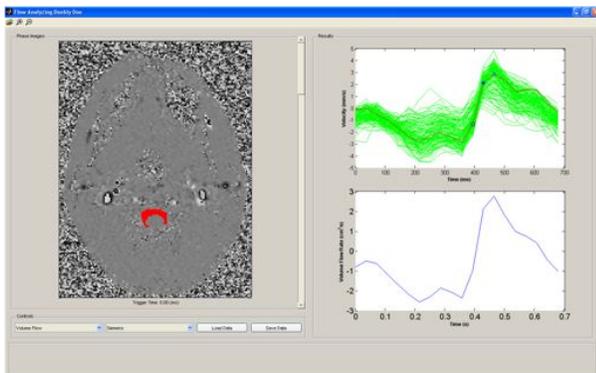

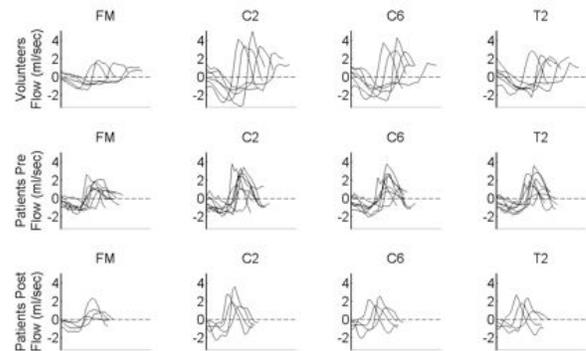**Figure 1.** pcMRI image segmentation interface showing a sample result.

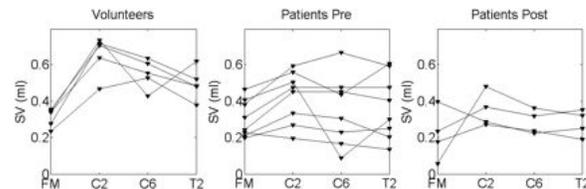**Figure 2.** CSF volume flow waveforms for each group

Figure 3. CSF stroke volume distribution for each group

RESULTS AND DISCUSSION

For both CMI patients and healthy volunteers, CSF flow was generally lowest at the FM, increased at the C2 level, and progressively dampened out at the C6 and T2 levels (Figure 2). The period of the pulsation was shorter in CMI patients pre- and post-surgery, indicating a more frequent pulse.

PQ was qualitatively smaller in pre-surgery CMI patients than in healthy volunteers, but no statistical difference was found. Likewise, no statistical differences in PQ for pre- and post-surgery CMI patients were found, despite the dampening observed in post-surgery waveforms. SV in pre-surgery patients was found to be statistically different from that in volunteers at C2 ($p<0.01$) and C6 ($p=0.035$). Despite post-surgical decreases in SV at all four levels (Figure 3), no statistical differences between pre- and post-surgery SV were found.

Post-surgery changes in CSF flow waveforms at the FM, C2, C6, and T2 levels revealed promising qualitative trends. However, the limited number of data sets does not allow for sufficient statistical power to draw broader quantitative conclusions.

Limitations

Patients and volunteers were age-matched, but not gender-matched; all eight patients were female and differences may be attributable to gender. Velocity image segmentations were performed by a single operator and not tested for reproducibility.

CONCLUSIONS

• Qualitative trends and small quantitative differences in CSF flow between CMI patients and healthy volunteers are promising at this point

• More CMI patient data sets are necessary to increase statistical power.