Lumbar Spine CSF Velocity Measurements in Tethered Cord Patients

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Importance for Chiari patients

The relative distribution of CSF motion along the spine is thought to be an important aspect to consider for Chiari patients. For example, elevated CSF motion in the upper cervical spine has been associated with Chiari. In this work, we quantify the CSF flow dynamics in the lumbar spine for tethered cord patients, a condition that can occur alongside Chiari malformation. The results from this study help us to understand normal and abnormal CSF dynamics in the spine.

Abstract

MRI measurement of sagittal CSF velocity was obtained for six patients with tethered cord syndrome. A MATLAB code was developed to analyze the data and quantify velocities in the dorsal and ventral lumbar CSF space. Results showed that peak CSF velocity in the lumbar spine were ~4.5 cm/s; a value much greater than that measured in healthy subjects in the literature. Complex bidirectional CSF flow with areas of local 'jets' were observed.

Introduction

The origin and distribution of the oscillatory CSF movement in the spine has been debated. Some have contended that the CSF pulse within the spine is primarily due to the arterial expansion within the cranial vault leading to CSF being pushed out of the cranial cavity and into the more compliant spinal subarachnoid space. Others have conjectured that the CSF pulse in the spine could be due to both arterial expansion in the cranial vault and also more directly due to expansion of vessels within the spinal cord. In healthy people, it has been observed that very little CSF pulsation occurs in the lumbar spine. We hypothesize that a greater CSF pulsation will be present in tethered cord patients than in healthy subjects.

Methods

Our approach was to obtain MRI measurements of CSF velocity in the sagittal plane from six tethered cord patients in the lumbar and/or thoracic spine. The MRI measurements were pre-processed using SEGMENT (Lund, Sweden) and a custom MATLAB (Natick, Ma) post-processing algorithm. CSF flow was quantified based on measurement of dorsal and ventral a) peak, b) minimum and c) peak-to-peak velocities.

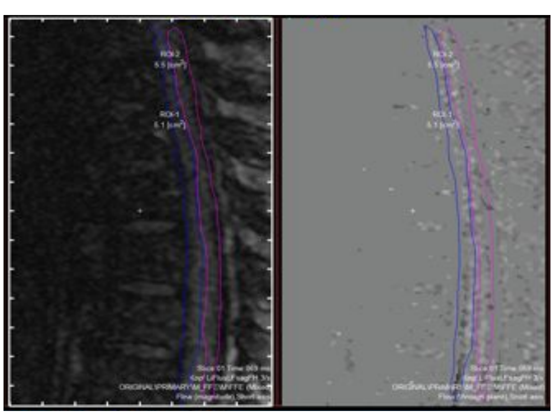

Figure 1. Selection of the region of interest in the thoracic spine for a tethered cord patient. Blue line indicates the ventral CSF space, violet line indicates the dorsal CSF space analyzed (Left: MRI magnitude image. Right: MRI phase contrast image).

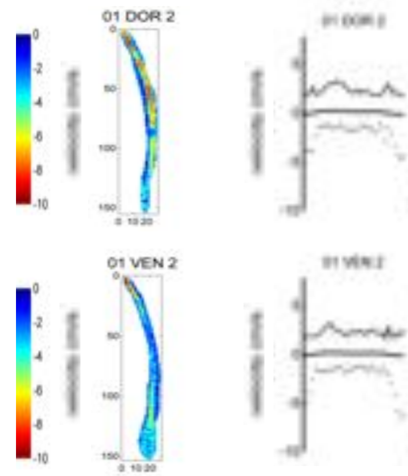

Figure 2. Spatial distribution of z-direction velocity on the dorsal and ventral CSF space (left). Peak (dashed), average (solid) and minimum (dots) velocity within the region of interest.

Results and Discussion

Overall maximum velocities in the dorsal and ventral side of the CSF space for the six subjects analyzed were 4.34 cm/s and 4.54 cm/s, respectively (Table 1). Evidence of strong bidirectional flow was found within each ROI (Figure 2, right). Thus, CSF was found to have a complex distribution of motion. Locally elevated CSF velocities or 'jets' were observed on both the dorsal and ventral side of the spinal cord (Figure 2, left).

Table 1. CSF velocities quantified in the dorsal and ventral CSF space in terms of max, min and peak-to-peak values.

	Dorsal (cm/s)			Ventral (cm/s)		
subject	max	min	pk-pk	max	min	pk-pk
01	3.47	-5.55	9.02	2.88	-5.10	7.98
02	2.94	-3.71	6.65	4.08	-4.84	8.91
03	4.33	-6.21	10.54	4.37	-4.96	9.33
04	4.06	-4.35	8.40	3.79	-4.37	8.17
05	4.33	-6.75	11.07	5.38	-5.75	11.13
06	6.92	-7.82	14.75	6.75	-6.78	13.53
AVERAGE	4.34	-5.73	10.07	4.54	-5.30	9.84

Conclusions

- Tethered Cord patients were found to have elevated CSF velocities in the lumbar and thoracic spine
- Complex bidirectional CSF flow with local jets was observed
- The results support that a the source of the CSF pulsation could in part be due to arterial expansion in the spine

References

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