First Upright Study of CSF Flow in Chiari I Malformation with Cine Phase-Contrast MRI

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Introduction

Chiari malformation type I (CMI) is the condition of excessive downward protrusion of the cerebellar tonsils beyond the foramen magnum. Structural MRI is the main imaging diagnostic tool, often accompanied by cine phase-contrast (PC) MRI of the cerebrospinal fluid (CSF) flow. Due to the susceptibility of a sub-type of this disease[1] and CSF flow in general[2] to gravitational pull, imaging the patient in the recumbent position is less than ideal. The goal of this work is to explore for the first time the utility of upright MRI in the diagnosis of CMI.

Method

A 42 years old female CMI patient with symptoms of headache, pain in the neck, back and limbs, dizziness and drop attacks was imaged in a vertical Upright MRI scanner (Fonar, NY). The scanner has a bed that can be rotated to any angle between the vertical and horizontal position. The patient was imaged in the vertical seated position and the recumbent supine position. Besides regular structural scans, CSF flow and spinal cord motion were imaged in a mid-C2 axial and midline sagittal slice with an ECG-gated cine PC sequence.

Results

Structurally, there was a small increase of tonsillar descent on moving from the supine to the upright posture. Right (left) tonsillar descent below the foramen magnum was 15.9±0.8 mm (11.6±0.3 mm) when upright and 14.3±0.6 mm (9.9±0.7 mm) when supine. Right tonsil was lower than the left tonsil in both postures.

The midline sagittal cine CSF flow appeared to be quite normal when the patient was supine (Fig. 1b) other than the expected cisterna magna CSF volume reduction. However, on assuming the upright posture, there was a significant obstruction of CSF flow anterior to the brain stem around the clivus region (Fig. 1a) throughout the whole cardiac cycle. Furthermore, CSF flow in the spinal canal at the mid-C2 level became spatially inhomogeneous in the upright posture (Fig. 1c) compared to the supine (Fig. 1d) posture during systole. Diastolic CSF flow was quite spatially uniform in the CSF space for both postures.

Fig. 2 shows the quantitative total CSF flow rate and spinal cord velocity at the mid-C2 level. The CSF flow waveform in both the supine and upright posture were within the normal range (Fig. 2a). However, the spinal cord diastolic peak velocity was larger and earlier than normal in the supine posture (Fig. 2b). This abnormal motion was also visually evident in the cine movie of the magnitude images of the midline sagittal cine PC scan.

Conclusion

If this patient were to be imaged in the recumbent supine position alone, the CSF flow pattern could have been classified as non-outstanding. Major abnormalities of CSF flow in the upright posture would have been missed. Supplemented by the fact that we spend the majority of our lives upright and patients often report posture-dependent symptoms, upright imaging of CMI patients should be an indispensable part of a comprehensive examination. It also opens up a new avenue of research into the symptomatology of CMI.

References

1. Milhorat et al, J. Neurosurg. Spine, **7**, 601-609, 2007; 2. Alperin et al, JMRI, **22**, 591, 2005

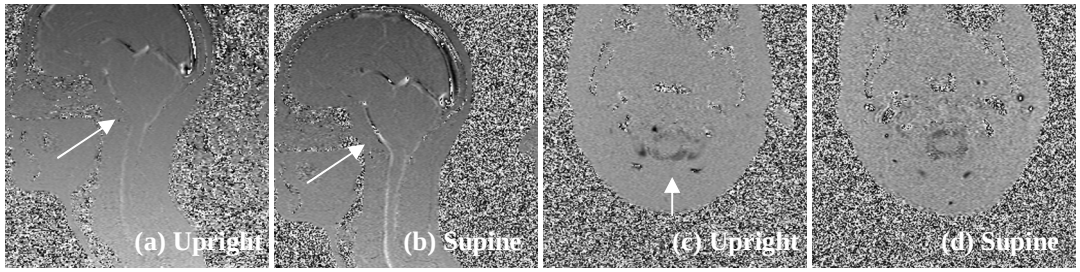

Fig. 1 (a) Obstruction of CSF flow (arrow) when upright. (b) Patent flow when supine. (c,d) Much faster (darker) posterior systolic flow (arrow) when upright.

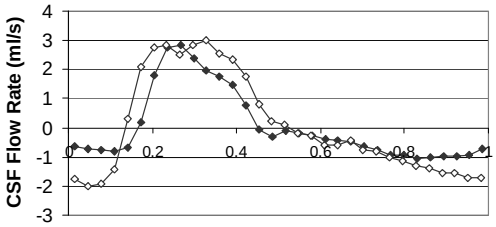

Fig. 2(a)

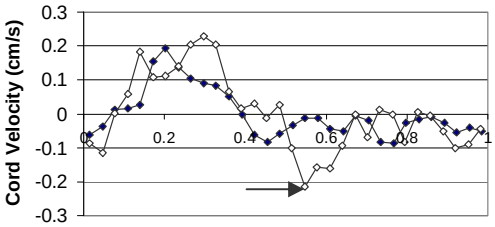

Fig. 2(b)

Fig. 2 (a) Total CSF flow rate and (b) velocity of spinal cord at mid-C2 level. Arrow indicates unusual diastolic cord pulsation. [Open diamond (supine), solid (upright)]