Technique for acquiring MR images of CSF flow during a Valsalva maneuver

A. L. Wentland[1,2], O. Wieben[1,2], C. A. Mistretta[1,2], F. R. Korosec[1,2], V. M. Haughton[2]
[1]Medical Physics, University of Wisconsin, Madison, WI, United States, [2]Radiology, University of Wisconsin, Madison, WI, United States

INTRODUCTION

Chiari I malformation is characterized by the abnormal protrusion of the cerebellar tonsils into the foramen magnum. This abnormality has been shown to alter the normal velocity patterns of cerebrospinal fluid (CSF) [1]. A large fraction of Chiari I patients performing a Valsalva maneuver experience headaches. Hypothetically, this physiologic maneuver exacerbates CSF flow abnormalities. Therefore, we studied CSF flow in the foramen magnum during rest and during a Valsalva maneuver, which requires images to be obtained within a breath hold. In this study we use a cine phase contrast undersampled projection reconstruction (PR PC) technique for acquiring velocity data with higher spatial and temporal resolution per unit time than is possible with a commercially-available cardiac-gated phase contrast imaging sequence (Fourier method). Previous phantom studies [2] have confirmed the accuracy of flow measurements over a range of velocities obtained with the PR PC method within the time of a breath hold. Here we present our results using undersampled PR PC for rapid flow measurements during rest and during the Valsalva maneuver in patients and volunteers.

MATERIALS AND METHODS

Cine phase contrast data were obtained with a previously validated undersampled projection reconstruction (PR PC) technique [2]. Scans were performed on a 1.5 T MR scanner (Excite HD, GE Healthcare, Milwaukee, WI) with a standard birdcage head coil (GE Healthcare, Milwaukee, WI). Undersampled PR PC images in the foramen magnum were obtained in 5 normal volunteers and 10 Chiari I patients with and without the Valsalva maneuver. Undersampled PR PC images were obtained with the following parameters: flip angle = 30°, NEX = 1, TR/TE = 6.4/3.0 ms, RBW = ± 31.25 kHz, FOV = 24 – 34 cm, slice thickness = 5 mm, and frequency encoding values = 256. Scans were performed with 64 and 32 projections with 1 or 2 views per segment (vps). For comparison, a cardiac-gated PC Fourier acquisition was also used with TR/TE = 11.2/5.6 ms, phase encoding values = 128, vps = 2, a ½ FOV, and 256 data points along the readout direction. The scan time for the Fourier acquisition was prohibitively long for a Valsalva technique. A temporal plot of CSF flow with and without the Valsalva technique was prepared from the images and used to compare a normal subject with a Chiari I patient.

RESULTS AND DISCUSSION

Flow measurements obtained from the undersampled PR PC acquisition showed significant differences in the flow patterns for patients and normal subjects during the Valsalva maneuver, as demonstrated in Figure 1. In volunteers breathing normally, CSF flow at the beginning of the cardiac cycle is in a caudad direction (positive sign) at a rate of 0.2 - 0.3 ml/s. Later in the cardiac cycle, the flow is in the cephalad direction (negative values) and then at the end of the cardiac cycle returns to a caudad direction. For the same subject performing a Valsalva maneuver, the flow rates are not significantly changed. For a subject with a Chiari I malformation, CSF flows in a caudad direction early in the cycle, then a cephalad direction and finally a caudad direction again. The flow during normal breathing has a slightly greater magnitude (0.5 ml/s) in the caudad and cephalad directions than it does in normal subjects. During the Valsalva maneuver, the flow is increased to a magnitude of greater than 1 ml/s.

CONCLUSIONS

With the undersampled PR PC acquisition, CSF flow can be imaged in the foramen magnum within the time span of a breath hold or Valsalva maneuver with high spatial resolution. The flow in the patients during the Valsalva maneuver showed significant differences from the normal subjects. The undersampled PR PC method may aid in selecting patients for surgical treatment of the Chiari I malformation. We are also investigating the use of HYPR [3], a novel acquisition and reconstruction technique for undersampled PR PC acquisitions to provide increased temporal resolution. Higher temporal resolution will allow for better sampling of the CSF flow waveform or for shorter scan times with acceptable temporal resolution. With HYPR the scan times can be reduced so that multiple flow waveforms can be acquired in a single breath hold.

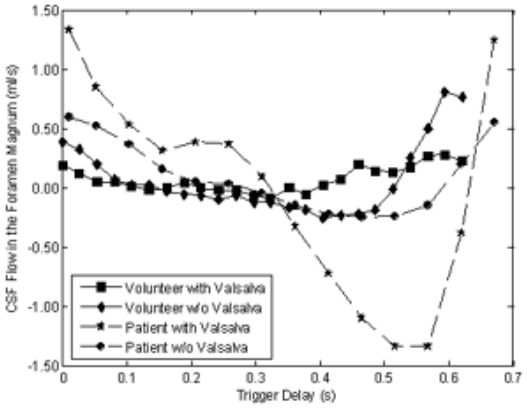

Figure 1. Plot of CSF flow in the foramen magnum in a patient and a normal volunteer with and without a Valsalva maneuver.

REFERENCES

[1] Wolpert *et al.* AJNR 1994;15:1299-1308. [2] Wentland *et al.* Procs. of 13th ISMRM. 2005, 1736. [3] Mistretta *et al.* MRM. Accepted.