Optimizing phase contrast MR for CSF flow analyses in Chiari malformation

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INTRODUCTION

The Chiari I malformation is characterized by downward displacement of the cerebellar tonsils into the upper cervical spinal canal, where they may theoretically obstruct the flow of CSF into and out of the cranial vault. Some symptomatic Chiari I patients require surgical decompression while other asymptomatic patients do not. CSF flow has been analyzed in these patients with the goal of developing a functional test to identify early those patients who require treatment. Conventional PC MR in a single slice at the foramen magnum has demonstrated significantly elevated CSF velocities in symptomatic Chiari I patients. Faster and higher resolution acquisitions are needed to characterize CSF flow at multiple levels and with the neck in positions of flexion and extension and during the performance of a Valsalva maneuver. Hypothetically, an undersampled radial projection MR method such as Phase Contrast with Interleaved Undersampled Projections -- PIPR[1], applied to the imaging of CSF flow, improves the acquisition time sufficiently to permit multiple slices and multiple patient positions. The purpose of this study was to assess image quality and accuracy of the PIPR method for CSF flow imaging.

MATERIALS AND METHODS

A version of PIPR was modified for CSF flow measurement and tested. Data was acquired in a phantom (Quest) with a computer driven pump and tubing. The pump was programmed to provide various rates and types of flow, including constant flow, and "carotid" flow at rates of 2, 4 and 8 cm/sec. A loop of the tubing was placed on a commercial phantom so that flow in two directions was measured. Flow measurements were acquired with PIPR and PC MR. With PC MR, up to 19 phases were collected in one 3 minute acquisition. With PIPR, images were collected in 26 sec, with the number of phases acquired depending on the parameters chosen. Images were acquired in a normal human volunteer with the PIPR and conventional PC MR techniques. The image quality in the two acquisitions was compared by inspection. Specifically the severity of ghosting and background streak artifacts on image quality were assessed.

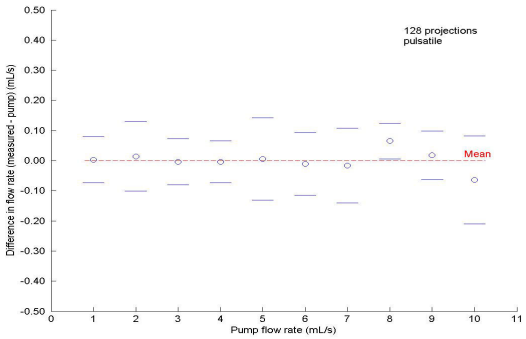

Figure 1. difference between measured and preset flow rate in the flow phantom.

RESULTS AND DISCUSSION

In the flow phantom, where the pump precision is 0.01 ml/sec, flow rates calculated from PIPR images correlated within 5 percent of all velocities calculated from the PC MR data. Figure 1 shows a Bland-Altman analysis of 128 projection scans with the mean of difference between measured and preset flow rates in the flow phantom indicated by the circles, two times of standard deviation around the mean indicated by the error bars. Flow plots from PC MR and PIPR (at the preset flow rate of 1.96 cm3/sec and VENC of 13cm/sec) appeared similar as shown in figure 2. In the human volunteer, the PIPR images demonstrated CSF flow effectively, with little interference from the expected artifacts due to undersampling as shown in Figure 3.

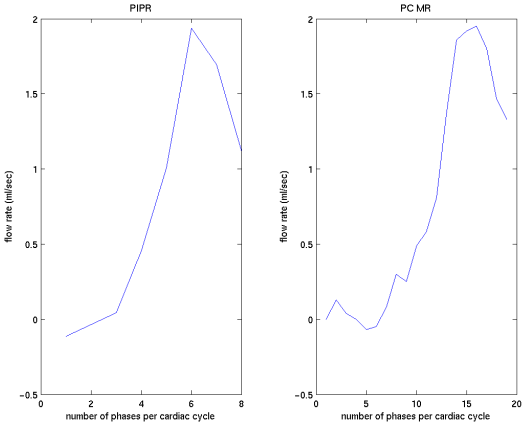

Figure 2. Flow rate measured in flow phantom using PIPR (left) and PCMR (right)

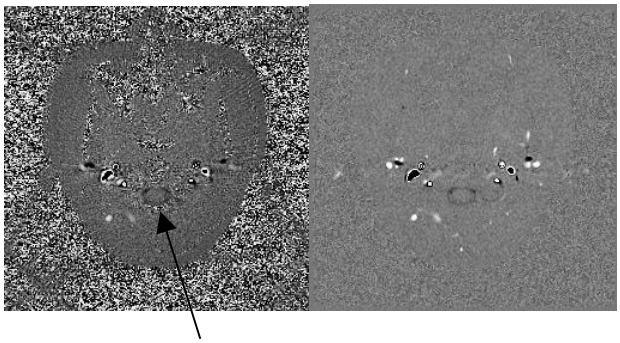

Figure 3. CSF Phase Difference images acquired using PIPC(left) and Cartesian PCMR (right)

CONCLUSIONS

PIPR, an accurate and faster imaging technique than PC MR, facilitates the measurement of CSF flow in normal volunteers. Future studies will extend this work to the measurement of CSF flow in Chiari patients in multiple contiguous slices under neck flexed, extended and in neutral position all within 30 minutes.

REFERENCES

1. Barger, et al., MRM, 43:503-509, 2000.
2. Bland,et al, 1(8476):307-10, 1986