4D contrast enhanced MRA with flow measurements (HYPR FLOW) in Arteriovenous Malformations

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INTRODUCTION

Phase Contrast (PC) HYPR FLOW, which employs post contrast PC VIPR images as the composite and reconstructs the first pass time resolved contrast enhanced VIPR acquisition using HYPR LR technique [1], is able to achieve 4D Contrast Enhanced (CE) MRA with both high temporal resolution and isotropic spatial resolution and quantitative flow dynamics from the PC images. PC HYPR FLOW was performed on normal subjects and patients with brain AVMs. 4D CE MRA images with sub-second temporal resolution and sub-millimeter isotropic spatial resolution were generated as well as the flow dynamic maps including the wall shear stress and pressure. Quantitative measurements of velocity, WSS and pressure gradients were conducted and compared between control and patient groups.

METHODS

Following contrast injection, a CE-MRA examination of the head is performed using time resolved multi-echo VIPR (ME VIPR). Subsequently, PC VIPR acquisition is acquired and then used as a composite image for HYPR LR reconstruction. The imaging parameters for ME VIPR were: FOV = 26x26x26cm^3, TR/TE = 3.1/0.4 ms, BW = 125 kHz, read out points were 64 per echo covering between the center to the edge of the k-space, frame update time was 0.5 s. The scan parameters for the post contrast PC VIPR acquisition were: FOV = 20x20x20cm^3, TR/TE = 12.5/4.8 ms, BW = 62.5 kHz, 7000 projections. Scan time is about 5 minutes. The contrast material was injected at a rate of 2-3mL/s. The contrast dose was 0.1 mm/kg for each scan. HYPR FLOW images were reconstructed using HYPR LR method with the complex difference image obtained from the PC VIPR acquisition as the composite. In the case when the subject moves between two scans, image registration between two scans can be applied by using a fully automated linear image registration tool (FLIRT) before HYPR LR reconstruction. Wall shear stress and pressure maps were calculated based on the flow information obtained from PC VIPR. WSS measurements were placed on carotid arteries, basilar artery, middle cerebral arteries (MCA) and angular arteries. Pressure gradients were measured between MCA and angular arteries. Average flow measurements were taken on MCA and angular arteries. For patients with AVM, additional measurements of WSS and average flow were taken on the main feed arteries and the corresponding arteries on the contralateral side.

RESULTS AND DISCUSSION

PC HYPR FLOW was performed on 10 healthy volunteers and 10 patients with brain AVM. All HYPR FLOW images have been reconstructed successfully with 0.68x0.68x0.68 mm^3 isotropic spatial resolution and 0.75 s temporal resolution. Flow dynamics (average flow, WSS and pressure gradient) were calculated and analyzed for each subject. It should be noted that accurate WSS measurements from PC velocity data, especially in vessels with strong pulsatility require spatial resolutions not generally achievable with PC MR. While PC VIPR is capable of achieving higher resolutions than standard protocols, we accept that there will be some error and plan to use it as a surrogate parameter related to the actual WSS. Figure 1 shows an example of WSS maps from a healthy volunteer (left) and a patient with brain AVM (right). Figure 2 shows the histogram of the relative WSS in the carotid arteries from the corresponding healthy volunteer (left) and the patient with brain AVM (right). For the healthy volunteer, the WSS distributions from left and right carotid arteries are similar, however, for the AVM case, the distribution from the lesion side shifts to the right indicating that a majority of voxels on the lesion side have increased WSS. For the control group, the measurements of the average WSS in the MCA, angular arteries and carotid arteries did not show significant difference between the two hemispheres (P>0.1). For the AVM patient group, the measurements of the average WSS in the MCA, angular arteries and carotid arteries on the lesion side are significantly higher than the contralateral side (P<0.01). The average WSS in the basilar artery from the patient group is higher than that from the control group (1.02 vs. 0.87 N/m2), however, the difference is not statistically significant (P=0.12). Figure 3 shows the average WSS in the largest feeding artery is significantly higher than the contralateral artery for all AVM patients. The difference is statistically significant (P=0.002). Mean flow measurements from the feeding artery are also significantly higher than the contralateral artery (P=0.003). For the control group, pressure drops from MCA to angular artery did not show significant difference between two hemispheres. For some of the AVM patient group, larger pressure drops were observed from MCA to angular artery on the lesion side than the contralateral side. However the difference is more sensitive to the location of the AVM lesion.

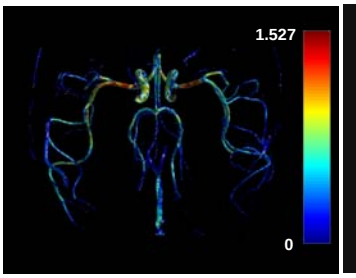

Figure1 WSS maps from a healthy volunteer (left) and a patient with brain AVM (right).

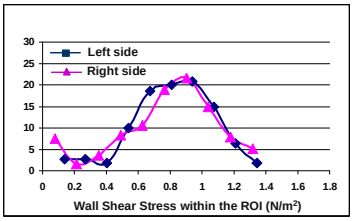

Figure 2 Histogram of the relative WSS in the carotid arteries from the corresponding healthy volunteer (left) and the patient with brain AVM (right). For AVM patient, WSS distribution from the lesion side shifted to the right indicating that a majority of voxels on the lesion side have elevated WSS.

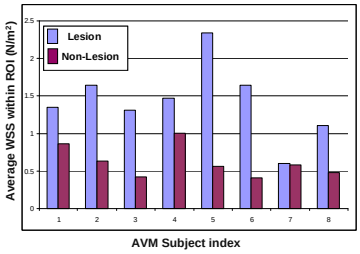

Figure 3. Paired comparison of the average WSS in the largest feeding artery (lesion) and the contralateral artery (non-lesion) for each AVM patient.

CONCLUSIONS

HYPR FLOW is able to provide whole brain time-resolved contrast-enhanced MR angiograms (4-D CE-MRA) with measurements of flow, pressure gradients and WSS, which allow investigation of physiological and pathological information.

REFERENCES

1. Mistretta CA, et all, *Magn. Reson. Med.*, 55(1):30,2006.
2. Johnson KM, et al, *Magn. Reson. Med.*, 59(3):456-462, 2008.

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