Evaluation of aneurysm hemodynamics using Phase Contrast Vastly undersampled Isotropic Projection Imaging

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Introduction

Currently, the size, morphology, and location of aneurysms are evaluated as possible predictors of rupture in the diagnosis of vascular disease. However, more reliable predictors for which aneurysms are at risk of rupture are needed. None-invasive dynamic physiologic measurements, such as intra-aneurysmal pressure and flow, could add tremendously to our understanding of which aneurysms are at higher risk of rupture. Using a novel MR imaging sequence, PC VIPR, we have obtained correlative intra-aneurismal pressure measurements in the canine bifurcation and side wall aneurysm model; and demonstrated methods for both qualitative and quantitative fluid velocimetry.

Methods

In compliance with our institutes animal review board, bifurcation aneurysms were surgically created canine carotids. A microcatheter was used to measure average pressures at the parent vessel, aneurysm neck, and sac. Immediately following these measurements, images were acquired using PC VIPR as well as several typical angiographic MR sequences including a contrast-enhanced MR angiogram on a clinical 1.5T MRI scanner (Excite HD, GE Healthcare, Waukesha, WI). PC VIPR is a 3D undersampling radial method in which sparse image volumes may be sufficiently characterized up to 50x faster than a conventional Cartesian sequence [1]. The previously reported implementation of cine PC VIPR [2] was improved to provide a higher frame rate within the cardiac cycle by a novel view ordering scheme and the use of balanced bipolar gradients. Using an adaptive radius temporal filter, at a central resolution of 36ms, this method was employed to acquire ~20 cardiac phases of a 20 x 20 x 15 cm FOV at 0.7 mm isotropic resolution in about 10 min. Dynamic velocity and complex difference images were reconstructed and used for a comprehensive analysis of several hemodynamical measures. Flow measurements were performed at the neck and left and right outflows using reformatted planes from PC VIPR. 3D Velocity vector plots were created to allow for qualitative display of the velocity distribution. Navier-Stokes fluid dynamics were employed to create relative pressure maps directly from the velocity information [3]. At this point two canines have been imaged and seven additional canines are in the study phase.

Results

Both studies shows qualitative correlation of the relative pressure gradients; however at the time of the first exam, technical limitations hindered correlation of pressure gradients. After subsequent improvements, including higher temporal resolution and more balanced projection ordering, close correlation was found in 5 of 6 regions with a mean difference of 0.7 mmHg (range 0.03 to 1.7 mmHg) (Figure 1). Velocity vector plots were found to excellently portray the complex flow pattern within the vessel. The flow measurements were comparable to those found using a 2D Cartesian sequence in the selected plane. Complex difference measures obtained using PC VIPR were found sufficient for basic visualization. However, the anatomical characterization was limited by insensitivity to slow velocities within the aneurysm sac, as shown in figures 1 and 2.

Discussion

Our results, demonstrate the feasibility of non-invasively obtaining additional fluid dynamical parameters which may allow for better characterization of aneurysm morphology and potentially serve as a better predictor of rupture. The ongoing study with seven additional animals will provide data with more statistical power to compare the noninvasive MR measurements with data obtained from invasive pressure measurements.

References

1. Gu et Al. AJNR. 26:743-749
2. Johnson et al. Proceedings ISMRM 2005

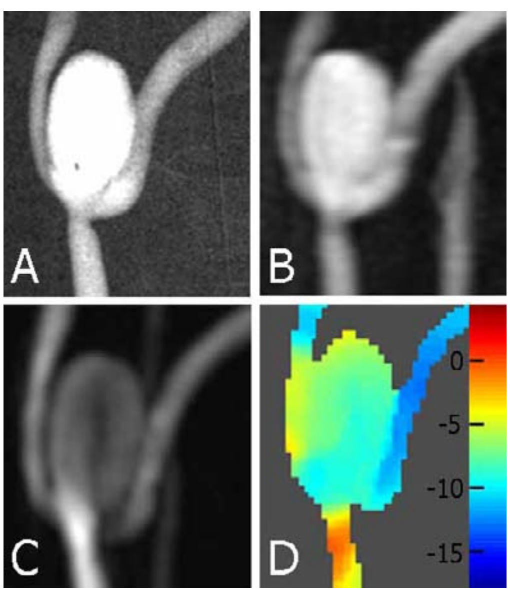

Figure 1. X-ray DSA(A), CE MRA (B), complex difference PC VIPR(C) and pressure(D) images of the aneurysm model. Pressure values are in mmHg.

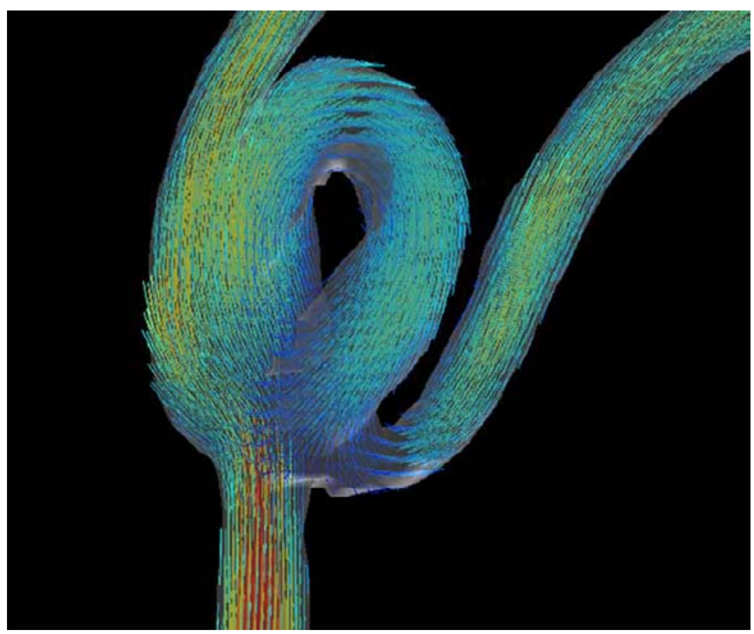

Figure 2. Average velocity vector plot obtained using PC VIPR. Vectors are colored by velocity with red representing higher velocities .Note, low velocities in the center of the aneurysm lead to a donut-type shape in the threshold visualization.