Transtenotic pressure gradient measurements using Phase Contrast Vastly Undersampled Projection Imaging (PC-VIPR) in a Canine Model

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Introduction

Imaging of carotid stenosis for potential revascularization surgery currently requires correlation of at least two non-invasive imaging studies or an invasive X-ray angiogram. MRA is often utilized as part of the imaging paradigm for this workup. We have previously reported on a novel MR based imaging sequence, PC-VIPR which can acquire velocity encoded images at speeds up to 50 times that of standard Cartesian imaging by means of angular undersampling [1]. Recently we have been able to utilize this sequence to calculate pressure changes across areas of stenosis from the image data. In a single examination, this technique can produce both images of the vessel lumen as well as quantitative flow and velocity data. In this study, we evaluate the ability of PC-VIPR to ascertain transstenotic pressure gradients across carotid stenoses in a canine model.

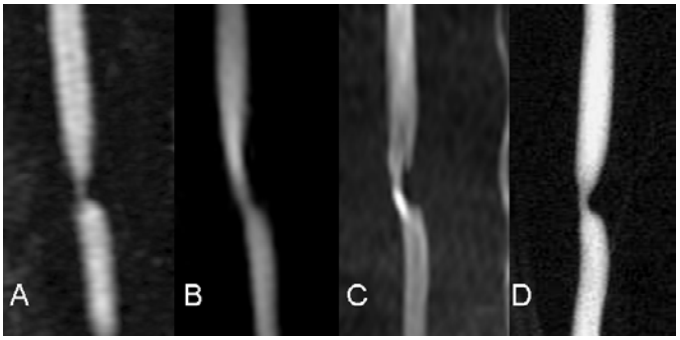

Figure 1. Anatomical Images of Stenoses using CE(A), PC VIPR(B), TOF(C), and DSA(D).

Methods

In compliance with our institutes animal review board, a focal stenosis was surgically created in each common carotid artery of 10 canines. The degree of stenosis was determined from DSA images utilizing methods outlined in the NASCET trial. As part of the angiographic procedure a microcatheter was selectively positioned in the vessel proximal and distal to the stenosis to obtain average pressure readings. After removal of the catheter, a MRA workup was performed on a clinical 1.5T MRI scanner (Excite HD, GE Healthcare, Waukesha, WI), including 3D time of flight (TOF), contrast enhanced (CE), and phase contrast (PC) exams. CE and TOF sequences were performed with parameters used clinically. 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. The ECG-gated PC VIPR exam provided an acquired 256^3 image matrix over a 20 cm FOV. Cine velocity images were reconstructed using an adaptive temporal filter with a central temporal resolution of 36 ms/phase for ~20 reconstructed cardiac phases in 10 min scan time, as well as a composite complex difference image for lumen visualization. From the volumetric, 3D-flow encoded velocity images, Navier-Stokes fluid dynamical relations were used to create dynamic pressure maps. The time average trans-stenotic pressure gradients were compared to the pressure drops measured with the microcatheter. Anatomical images were also compared between the imaging techniques used.

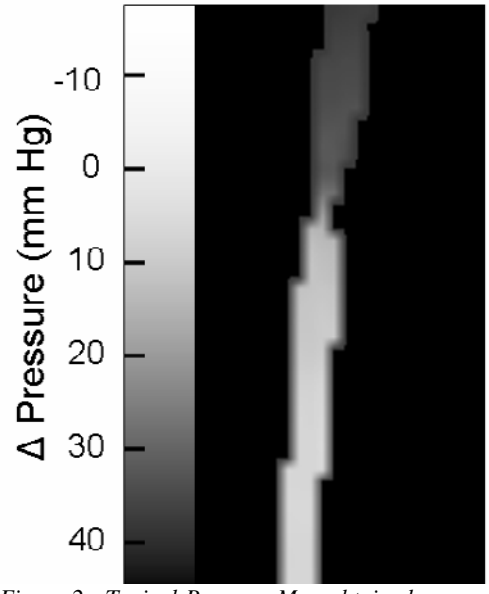

Figure 2. Typical Pressure Map obtained across a stenosis. The drop in his particular stensois was ~20mmHg.

Results

DSA and MRA images demonstrated degrees of stenosis ranging from 50 to 86% in the common carotid arteries. DSA and CE exams were found to have superior anatomical characterization, while TOF and PC VIPR images inherently rely on blood flow (Figure 1). Mean arterial pressure gradients ranging from 6 to 26 mmHg with corresponding arterial waveforms were obtained across the stenoses with direct invasive monitoring from a microcatheter. In 15 of 20 of the vessels, PC-VIPR pressure mapping was successfully performed. Typical maps are similar to that shown in Figure 2. The 5 cases that could not be evaluated with PC VIPR were stenoses of high degree (>70%). Excluding these cases and those done with an outdated version of the PC VIPR acquisition (4 stenoses), catheter and PC VIPR measurement were well correlated (R=0.74, Figure 3).

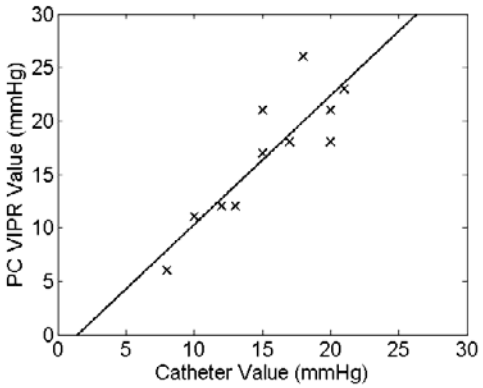

Figure 3. Correlation between PC VIPR and Catheter values. Linear regression fit found a correlation of 0.75.

Conclusions

With PC-VIPR, a novel MR imaging technique, data regarding both morphology and functional significance of a vascular stenosis may be evaluated. Coupling physiologic and anatomic data may improve the accuracy of and consolidate the non-invasive imaging evaluation of arterial stenosis. Further work in this area is currently underway.

References

1. Johnson *et al*. Proc. ISMRM 2005.
2. Gu *et al*. AJNR. 26:743-749