Sensitivity of Phase Contrast Derived Velocity and Stress Fields to Receiver Bandwidth at the Circle of Willis

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Introduction: Magnetic resonance (MR) imaging has the potential to measure blood flow velocity using phase contrast (PC) imaging sequences. CINE PC imaging allows a time series of velocity field to be acquired over the cardiac cycle. Wall stress estimation can be achieved through computational fluid dynamics (CFD) simulation [1]. Errors in the velocity measurement in the lumen have been ascribed to chemical shift artifact of the vessel wall, resulting in bias of up to 8% in the heart [2]. This effect can be mitigated by increasing receiver bandwidth (RBW) to reduce chemical shift effects [2]. Stress is of particular interest in the Circle of Willis (CoW) as it is the most common location for intracranial aneurysms [3]. We suspect that the sensitivity of kinetic fluid stress fields to RBW may be less in the CoW due to the absence of perivascular fat near the vessel walls. Errors that exist in the fluid velocity will skew stress estimates. In this study we sought to understand the effect of chemical shift errors on the velocity and stress measurements in the CoW.

Methods: Three healthy subjects were imaged with IRB permission. Imaging was performed on a 3 T MR scanner (Discovery 750, GE Healthcare). A large field-of-view (FOV) 3D PC sequence to localize the CoW and screen for cerebrovascular abnormalities was first acquired. A stack of thin 2D CINE PC slices was used to the repeatedly cover the CoW at several bandwidths (±15.63, ±31.25 and ±62.50 kHz) was then collected. Finally, a higher resolution 3D PC sequence matching the field of view of the CINE stack was collected to perform partial volume correction at a factor of 24 (~0.5 mm^3 voxel size). The temporal velocity field series were used as an input for CFD analysis. Vessel wall geometry for the CFD simulations was obtained from the high-resolution 3D PC data. Cut planes were placed in the left and right, internal carotid arteries (ICA) and middle cerebral arteries (MCA) to extract flow rates.

Results: Velocity measures showed tight tolerances for repeatability and did not show sensitivity to RBW. Fig 1 shows the extracted flow rate series from the right MCA for each normal subject and RBW. Fig 2 shows the temporal mean flow rates for each vessel, RBW and subject. Fig 3 shows the resulting near peak kinetic stress iso-surfaces for one subject at each RBW.

Discussion: Knowledge of hemodynamic parameters such as velocity and stress continues to improve understanding of several cerebrovascular diseases, including arteriovenous malformations and cerebral aneurysms. We have begun collecting images in these disease states. Irregular cardiac triggering and motion between scans is suggested for the bulk variation between scans in this study. Imaging with spin-echo sequences also showed a lack of perivascular fat near the CoW, further suggesting PC is not sensitive to RBW in the absence of perivascular fat.

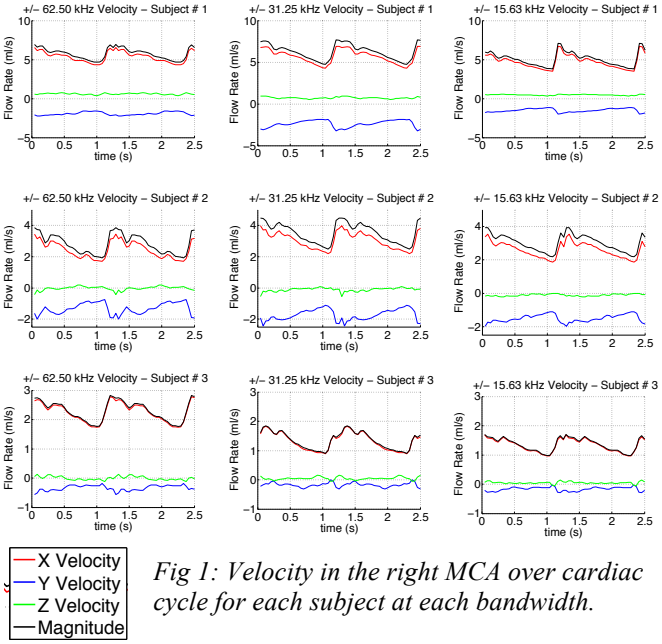

Fig 1: Velocity in the right MCA over cardiac cycle for each subject at each bandwidth.

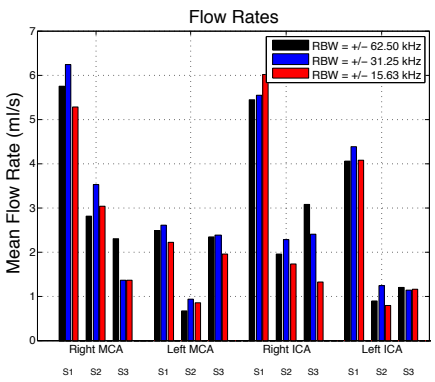

Fig 2: Mean flow rates for each artery, subject and reciever bandwidth

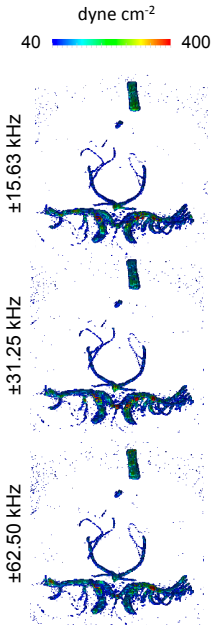

Fig 3: Near peak wall stress renderings in one subject at each of the reciever bandwidths

References

1. Cebral J, *et al.*, Hemodynamics in Normal Cerebral Arteries: Qualitative Comparison of 4D Phase-Contrast Magnetic Resonance and Image-Based Computational Fluid Dynamics, *J Eng Math* 2009**; 64**: 367-378.
2. Middione MJ, *et al.*, Chemical Shift-Induced Phase Errors in Phase-Contrast MRI, *Magn Reson Med,* 2012.
3. Winn HR, *et al.*, Prevalence of Asymptomatic Incidental Aneurysms: Review of 4568 Arteriograms, *J Neurosurg* 2002**; 96**: 43-9**.**