UNENHANCED TECHNIQUES FOR PERIPHERAL MRA: PHANTOM EVALUATION IN THE SETTING OF TRIPHASIC FLOW AND STENOSIS

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Introduction: Non-contrast based techniques for Magnetic Resonance Angiography (MRA) have experienced a resurgence with the association between Gadolinium contrast agents and Nephrogenic System Fibrosis (NSF). Several methods for peripheral angiography have been presented, however, their performance characteristics are poorly understood, particularly in the setting of clinically significant (≥50%) stenosis. Using a pulsatile flow phantom with a blood-mimicking solution, we sought to investigate the performance of several methods for non-contrast peripheral MRA under no and 50% stenosis. Investigated were variations of ECG-gated Quiescent Inflow with Steady-State (QISS) [1], ECG-gated Time of Flight (TOF) [2], non-ECG-gated Ghost HASTE (Ghost) [3], and subtractive ECG-Gated HASTE (FBI) [4] techniques.

Materials and Methods: A programmable flow pump (CompuFlow 1000MR, Shelly Medical Technologies, Canada) was used to drive a blood mimicking fluid (T1 = 850ms, T2 = 170ms) through a tube with an inner diameter of 0.25 inches. The fluid was pumped at eight different velocities in the shape of a waveform that mimics the triphasic flow profile of the femoral artery (Fig. 1). The phantom was submerged in a doped water bath imaged with a body and spinal coil on a 1.5T Siemens Avanto. Two variations of QISS (balanced SSFP and FLASH readouts; acquisition time [TA] = 1 min), TOF (TA = 5min), two variations of Ghost with different echo times (flip angle [FA] = 90°; readout spoiling = 25%; TA = 2 min; TE = 36ms and 88ms), and two variations of FBI using different refocusing flip angles (trigger times of 0 ms and 260 ms; TE = 36 ms; readout spoiling = 25%; TA = 2 min; FA = 90° and 180°) were acquired. This protocol was performed in the setting of no stenosis, and 50% stenosis, the latter created by inserting a fitting with 0.125 inch diameter into the tube phantom. The seven methods were evaluated quantitatively by comparing luminal signal measurements normalized to their maximum value for each technique. For all image stacks except with the projective Ghost method, mean signal measurements of the lumen were taken using a circular region-of-interest (ROI) tool on an axial source or reformatted slice at the center of the stenosis. Ghost signal measurements were taken from a 2D coronal image with a rectangular ROI centered along the length of the stenosis. Peak velocity was measured at the systolic peak of the triphasic flow waveforms in Fig. 1, which were obtained proximal to the stenosis using phase contrast imaging.

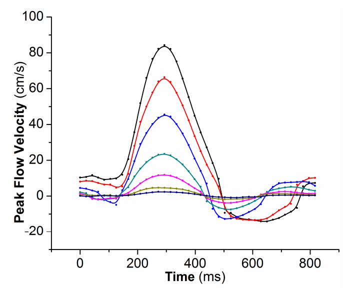

Fig. 1 Flow profiles obtained by phase contrast imaging.

Results: In the setting of 50% diameter stenosis, signal measurements for each MRA method followed different trends (Fig. 2). Between peak velocities of 0 cm/s to 15 cm/s, QISS, FBI, and Ghost signals rose to a maximum and then proceeded to diminish whereas TOF signal monotonically increased. For peak velocities between 15 cm/s to 80 cm/s QISS and TOF signals increased to unity while Ghost and FBI decreased towards zero. In the setting of no stenosis (Fig. 3), signal measurements for all techniques except FBI plateaued at unity, which contrasted with the diminishing signal of FBI and Ghost, as well as with the temporary decrease in QISS signal and slower rise of TOF signal at 50% stenosis. The MRA image quality varied with the technique and peak velocity (Fig 4). Under the waveform with a peak velocity of 84.25 cm/s, the stenotic segment was clearly seen in QISS and TOF. Conversely, the stenotic segment was not seen with the Ghost and FBI techniques at this velocity, or for waveforms with peak velocities ≥65 cm/s and ≥25 cm/s, respectively. At 84.25 cm/s, post-stenotic signal loss was seen with the TOF technique (arrow in Fig 4), presumably due to turbulence or deceleration of the fluid as it exited the stenosis. The other methods, except for FBI acquired with FA = 90°, did not display this artifact. At a velocity of 11.9 cm/s, the stenotic segment displayed signal dropout at both ends in QISS and TOF, but was visible along its entire length with Ghost and FBI. At 2.41 cm/s, the stenosis was more visible with QISS bSSFP than at 11.9 cm/s, but was barely visible for QISS FLASH and TOF. At this low velocity, the stenotic segment appeared hyperintense with Ghost and FBI relative to the non-stenotic segments, and appeared slightly elongated in Ghost. Across all velocities under 50% stenosis, Ghost (TE=88) and QISS bSSFP displayed better signal performance than their respective variations.

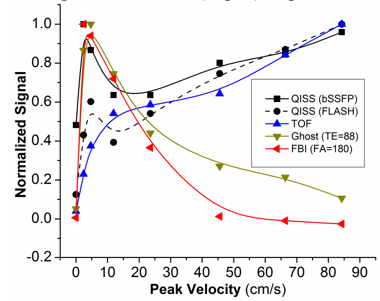

Fig. 2 Normalized signal vs. peak velocity of five MRA techniques at 50% stenosis.

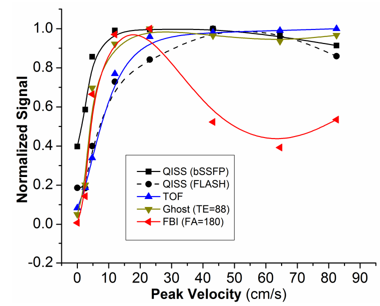

Fig. 3 Normalized signal vs. peak velocity of five MRA techniques at no stenosis.

Conclusion: The signal characteristics of the various techniques under the conditions of triphasic blood flow and stenosis were complex and observed to vary substantially. QISS imaging using a bSSFP readout provided the best signal performance across the widest range of peak velocities in normal and 50% stenotic tubular phantoms. TOF and QISS FLASH performed worse than QISS bSSFP at slower flow velocities, and TOF suffered from signal loss immediately distal to the stenosis at high velocities. Ungated Ghost and ECG-gated FBI techniques using the same fast spin-echo based readout demonstrated nearly identical patterns of signal behavior except that slightly larger signal intensity was obtained with the former for triphasic waveforms with peak velocities exceeding 25 cm/s and it displayed the stenosis for a larger range of velocities. Ghost performed better with TE=88 ms than TE=36 ms, displaying higher stenotic signal and image quality across all velocities, whereas FBI with FA = 90° and FA = 180° displayed negligible difference in stenotic signal but FA = 90° produced higher quality images with less artifact. The performance of these techniques under different flow patterns and degrees of stenosis requires further investigation.

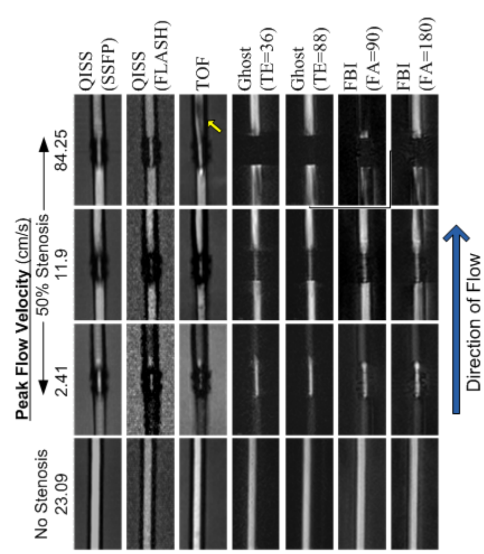

Fig. 4 Coronal thin MIPs through region of stenosis for each technique. Three velocities are displayed at 50% stenosis and one at no stenosis.

References: [**1**] Edelman et al. MRM *in press*. [**2**] Keller et al. Radiology 1989;173:527-532. [**3**] Koktzoglou et al. MRM 2009;61:1515-9. [**4**] Miyazaki et al. JMRI 1998;8:505-507.

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