Fast Inversion Recovery Magnetic Resonance Angiography (FIR-MRA) of the Intracranial Arteries

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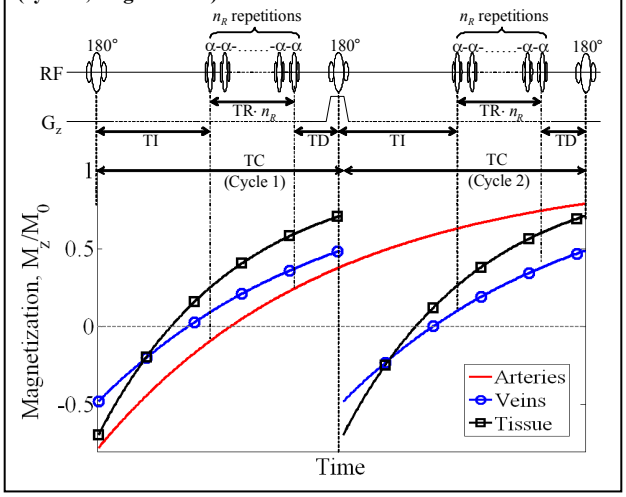
Introduction –3D time-of-flight (TOF) [1] provides excellent vessel-to-background contrast in intracranial MRA, but is subject to in-plane saturation and incomplete venous suppression. Spin-labeling [2-3] may be used to perform MRA [4-5], but typically requires long inversion intervals with inherently long acquisition times. We have developed a 3D fast inversion recovery MRA (FIR-MRA) that uses spin-labeling technique with reasonably short acquisition time. Initial results demonstrate superior vessel conspicuity, background suppression and venous suppression with 3D FIR-MRA compared to 3D TOF [6]. The purpose of this work is to perform a detailed comparison of FIR-MRA to TOF, and to demonstrate the clinical utility of FIR-MRA.

Fig. 1: FIR-MRA pulse sequence and signal simulation, showing consecutive non-selective (cycle 1, dark-blood) and selective (cycle 2, bright-blood) inversions.



Methods – Similar to spin-labeling with FAIR [2-3], FIR-MRA employs alternating non-selective and selective inversions (Fig. 1). In addition, the sequence is designed to simultaneously: (i) allow high vessel in-flow, (ii) null arterial blood during the dark-blood non-selective cycle, and (iii) null venous blood while providing T1-weighted tissue contrast in both cycles. FIR-MRA uses segmented acquisitions of n_r GRE acquisitions per cycle and self-calibrated parallel imaging [7] for acceleration. An off-resonance selective inversion provides effective venous suppression.

Intracranial imaging of 3D FIR-MRA and 3D TOF was performed at 3.0T (GE Healthcare, 8-element coil) with three-slab acquisitions of similar FOV and spatial resolution. FIR-MRA was acquired with TC/TI/TR/TE = 1600/750/9.5/3.2 msec, n_r = 60, flip angle = 15°, bandwidth = ±15.63 kHz, total slab thickness = 11 cm, and self-calibrated parallel imaging of R = 2 (time = 7.7 min). 3D TOF employed separately-calibrated parallel imaging (ASSET, R = 2, time = 6.5 min). Eight normal subjects were evaluated by consensus grading between two neuroradiologists for vessel conspicuity, continuity, and sharpness in nine types of arteries (internal carotid, vertebral-basilar, middle cerebral M1-M3 segments, M4 segments and beyond, posterior cerebral P1-P3 segments, P4 segments and beyond, anterior cerebral A1-A3 segments, anterior frontal branches, cerebellar). Presence of artifacts and venous signal were also evaluated. FIR-MRA was also compared against TOF and contrast-enhanced exams in three clinical studies; two evaluating coiled aneurysms, and one evaluating an arteriovenous malformation (AVM).

Fig. 2: Sagittal projections (25 mm thick) of the remnant (arrows) of a coiled aneurysm with (2a) TOF, (2b) contrast-enhanced MRA and (2c) FIR-MRA.

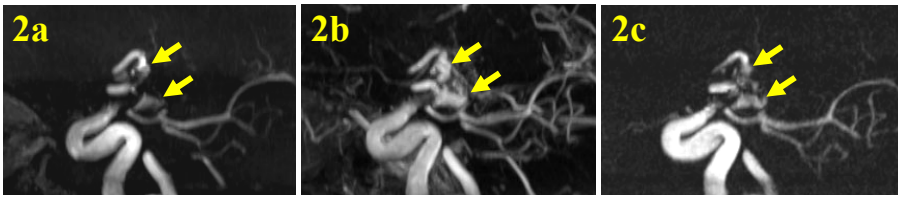
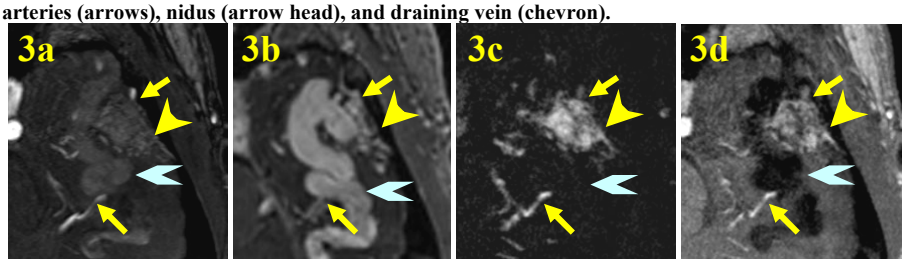


Fig. 3: Cropped, axial images of a left temporal lobe AVM acquired with (3a) TOF, (3b) contrast-enhanced MR venogram, and (3c) FIR-MRA with its (3d) bright-blood image, showing the feeding arteries (arrows), nidus (arrow head), and draining vein (chevron).



Results – FIR-MRA had superior vessel conspicuity in two vessel types (M4 and P4 and beyond), but inferior sharpness in four vessel types (P4 and beyond, A1-A3, anterior frontal branches, cerebellar). FIR-MRA had equal or better vessel continuity and venous suppression in every subject. In both aneurysm patients (Fig. 2), FIR-MRA (2c) depicted the aneurysm remnant better than TOF (2a). In the AVM patient (Fig. 3), FIR-MRA (3c) provided a clearer depiction of the nidus than TOF (3a) and contrast-enhanced MRV (3b). In addition, the feeding arteries, nidus, draining vein, and surrounding brain tissue were best differentiated on bright-blood FIR-MRA (3d). The vessel conspicuity, continuity and venous suppression of FIR-MRA were equal or superior to TOF in all patients.

Conclusion – FIR-MRA has equal or better vessel image quality than TOF in every category except sharpness. The initial clinical experience suggests that FIR-MRA provides superior depiction of coiled aneurysm remnants than TOF, and provides a new way to evaluate AVMs. A further evaluation of the clinical impact of FIR-MRA is warranted.

References – [1] Masaryk, Radiol 1989; [2] Kim, MRM 1995; [3] Kwong, MRM 1995; [4] Nishimura, MRM 1988; [5] Sallustio, Stroke 2008; [6] Tan, ISMRM 2009; [7] Tan, MRM 2009.