3D Fast Inversion Recovery Magnetic Resonance Angiography (FIR-MRA)

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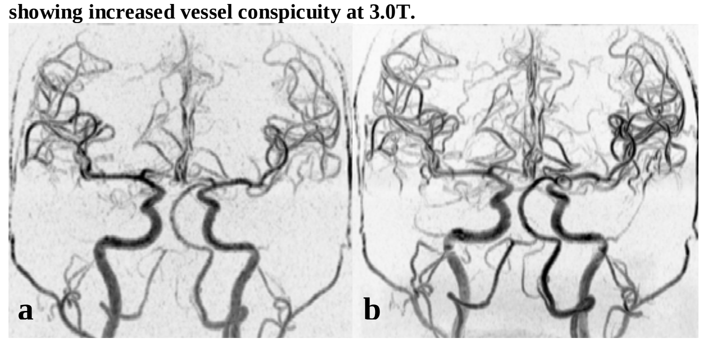
Introduction – With inversion-preparation, the difference between signals from selective and non-selective inversions can be used for non-contrast-enhanced MRA [1]. A magnetization-prepared rapid gradient echo (MP-RAGE) pulse sequence [2] can be adapted for MRA by choosing an inversion time (TI) that simultaneously nulls blood and provides tissue contrast. Because 3D MP-RAGE acquisitions can have long scan times, self-calibrated parallel acceleration is desirable [3]. Here we describe a fast inversion recovery MRA (FIR-MRA) technique for imaging the intracranial arteries, similar to conventional 3D time-of-flight (TOF) angiography [4].

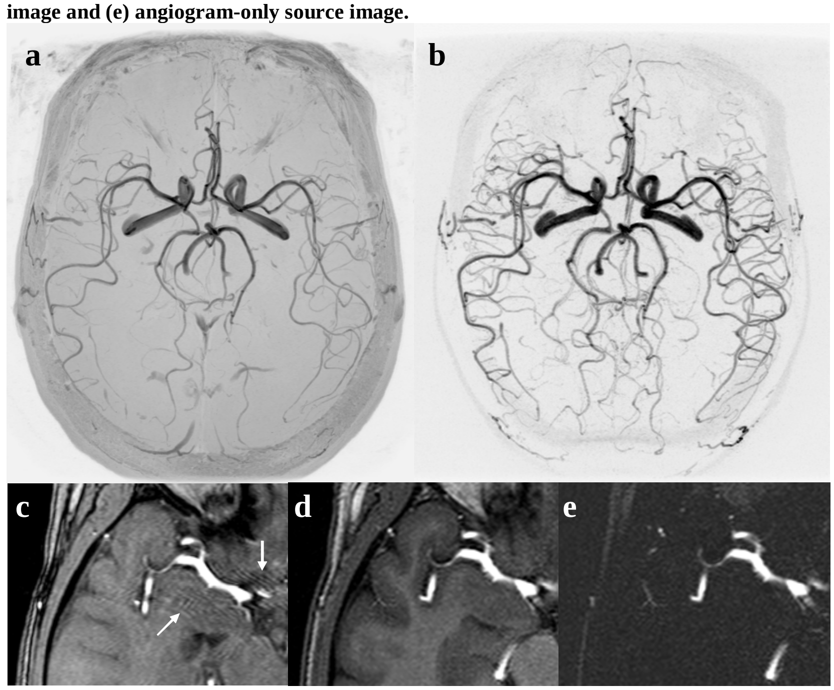
Methods – The basic 3D FIR-MRA technique employs two MP-RAGE cycles. In the first cycle, a selective inversion is applied axially to the imaging slab. Proximal blood flows into the slab during the TI interval, providing bright-blood signal. In the second cycle, a non-selective inversion nulls blood signal. Each cycle produces T1-weighted images, and the complex difference between them produces the angiogram-only source image. The selective inversion can be extended distally for venous suppression. The extent of vascular in-flow in FIR-MRA is not determined by progressive saturation, so there is potential for a thicker slab to be prescribed than in 3D TOF. Fig. 1a shows good vessel conspicuity in FIR-MRA at 1.5T using just two slabs. Static tissue is subtracted out, allowing projections to be viewed in any orientation. Imaging at 3.0T (b) can provide even higher vessel conspicuity.

Fig. 1: Coronal MIPs of two-slab FIR-MRA at (a) 1.5T and (b) 3.0T, showing increased vessel conspicuity at 3.0T.



Five normal subjects (ages 25 to 46) were imaged with a two-slab FIR-MRA at 3.0T (GE Healthcare, Signa 14), an 8-element coil and elliptical centric view order (Cycle Time/TI/TR/TE = 1500/850/9.5/3.2 msec, 40 SPGR repetitions per cycle, flip angle = 15°, FOV = 18 cm, sampled at 288×240×48, 0.6×0.7×1.4 mm^3, bandwidth = ±15.63 kHz, partial echo = 0.75, total slab = 11 cm). Parallel imaging with GRAPPA [3] was applied (R = 2, total scan time = 11 min). For comparison, a three-slab, 3D TOF was acquired (total slab = 10 cm, R = 2, time = 6.5 min). The criteria for evaluation were vessel conspicuity, background suppression, vessel sharpness, lumen uniformity, and presence of artifacts. A reader was presented with axial maximum-intensity-projections (MIP) and source images for scoring on a +2 to -2 scale where a positive score means higher image quality in FIR-MRA. Pseudo-source images were created by fusing angiogram-only and T1-weighted source images.

Fig. 2: Three-slab, 3D TOF – (a) axial MIP, and (c) a cropped source image, with presence of flow artifacts (arrows); two-slab, 3D FIR-MRA – (b) MIP, (d) pseudo-source image and (e) angiogram-only source image.



Results – FIR-MRA has superior vessel conspicuity (+2 in all subjects) and background suppression (+2 in 4 subjects, +1 in 1 subject), which can be seen comparing the MIPs (Fig. 2a, b). Fig. 2d shows that pseudo-source images have better artifact suppression (+1 in all subjects) than TOF (c) and provide an improved tissue reference. FIR-MRA also scored better in lumen uniformity (+1 in 4 subjects, 0 in 1 subject). Vessel sharpness was scored equal (0) in all but one subject (-1).

Conclusion and Discussion – FIR-MRA can provide improvements over standard 3D TOF in vessel conspicuity, background, artifact suppression, and possibly lumen uniformity but at longer scan time. Poorer vessel sharpness was observed at the slab interface. Small vessels may be better visualized in the angiogram-only image. A more detailed clinical evaluation is needed. Future work includes application to the carotid arteries, and imaging with higher acceleration factors.

References – [1] Nishimura DG, MRM 1988; [2] Mugler JP, MRM 1992; [3] Griswold M, MRM 2002; [4] Masaryk TJ, Radiol 1989.