Non-Contrast-Enhanced Renal Angiography in One Heartbeat

Hattie Zhi Chen Dong[1], Shreyas S. Vasanawala[2], and Dwight G. Nishimura[1]
[1]*Electrical Engineering, Stanford University, Stanford, CA, United States,* [2]*Radiology, Stanford University, Stanford, CA, United States*

Introduction: Existing inflow-based non-contrast-enhanced renal angiography methods [1] have demonstrated considerable promise but are affected by issues related to respiratory motion, background suppression and inflexible inflow times. Multiple inversion recovery (MIR) magnetization preparation [2] is an alternative that effectively addresses these issues. Recently MIR was combined with alternating TR balanced SSFP (ATR-SSFP) [3] to provide rapid volumetric imaging via 2D projective acquisition [4]. In this work, we explore practical factors to improve image quality, and demonstrate scans at various orientations and increasing levels of detail. Each image was acquired in one heartbeat, which is highly advantageous for respiratory artifact mitigation and real-time interactive assessment.

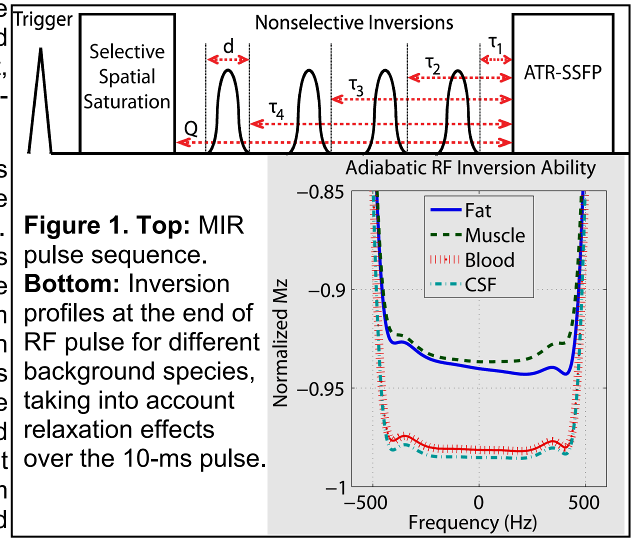

Figure 1. Top: MIR pulse sequence. **Bottom:** Inversion profiles at the end of RF pulse for different background species, taking into account relaxation effects over the 10-ms pulse.

Methods: MIR MRA uses spatial saturation and nonselective inversions to concurrently null a wide range of background T_1 species, while maintaining signal from blood flowing into the imaging region (Fig. 1 top).

The saturated slab, which contains the imaging volume, was oriented either axially to utilize inflow from the aorta when imaging the left and right renal arteries together, or sagittally to employ inflow from the main renal arteries when imaging distal vessels. The saturation region was extended beyond the imaging volume to suppress venous signals. Adiabatic hyperbolic secant pulses were used to perform the inversions. We simulated the pulse's inversion ability (Fig. 1 bottom), and took it into account during inversion timing calculations. This reduced fat signal at the end of the inflow period down to the level of 10^{-3}, from 10^{-2} if ideal inversions were assumed. The inversion timings were found by solving the optimization problem of minimizing the residual longitudinal magnetizations of the interested species after any given inflow time Q.

ATR-SSFP readout was chosen to provide good blood SNR with added fat suppression. Projection images were acquired in three types of scans, in which saturation/imaging excitations, and view orientation were respectively: 1) axial and axial; 2) axial and coronal; 3) sagittal and coronal. Shared parameters were: TE/TR$_1$/TR$_2$=1.72/3.44/1.16 ms; flip angle=50^o; resolution=1.25x1.25 mm^2. Scan type specific parameters were: 1) inflow=600 ms; inversions=47, 172, 366, 540 ms; FOV=32x32 cm^2; projection distance=4 cm S-I. 2) inflow=600 ms; inversions=47, 172, 366, 540 ms; FOV=32x12 cm^2; S-I imaging extent=6.4 cm; projection distance=entire A-P extent. 3) inflow=400 ms; inversions=103, 174, 214, 339 ms; FOV=12x32 cm^2; L-R imaging extent=3 cm; projection distance=entire A-P extent. Each image required only 1 shot / 1 heartbeat. ECG triggering placed MIR preparation during systole. Scans were acquired on a 1.5 T GE Signa scanner using an 8-channel cardiac coil.

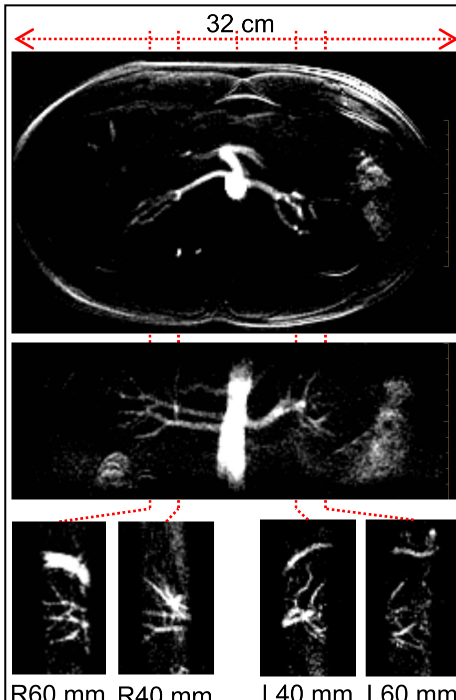

Figure 2. MIR projective angiograms. Top/middle: the entire renal region is imaged axially and coronally. Fine distal vessels are imaged in the bottom series. Each image was acquired in 1 heartbeat. Despite large projection distance (top: 4 cm S-I; middle/bottom: entire A-P extent 20-25 cm), suppression was excellent.

Results and Discussion: Figure 2 shows MIR projective angiograms. The axial projection (top) has excellent background suppression near the arteries due to a short projection distance of 4 cm, but contains high-frequency signals at the subcutaneous fat layer due to an imperfect ATR fat profile and rapid fat recovery during the long readout. In the coronal projections (middle/bottom), the shorter readout due to the rectangular FOV led to remarkable background suppression despite the full A-P projection distance (20-25 cm). The series of sagittal slab scans (bottom) is able to delineate fine levels of detail in the distal branch vessels. Further, MIR is robust against arrhythmia since only 1 shot is needed.

The SNR can be improved in several ways if needed. Motion-tracked signal averaging can be effective at some cost to scan time. Given the relative sparsity of MIR angiograms, compressed sensing can increase SNR through noise removal [5]. Further, adoption at 3T lengthens blood T_1, which would contribute to higher signal. MIR is a promising fast 2D projective imaging method offering intriguing advantages with respect to rapid assessment in the renal region.

References: [1] Miyazaki M, Eur J Radiol 80:9, 2011. [2] Mani S, MRM 37:898, 1997. [3] Leupold J, MRM 55:557, 2006. [4] Dong H, MRA Club, 13.32, 2011. [5] Cukur T, MRM 61:1122, 2009.