Optimization and Comparison of Non-Contrast-Enhanced Inflow-Sensitive Inversion Recovery bSSFP for Renal and Mesenteric MRA at 1.5T and 3.0T

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Purpose: Patients with kidney disease are most likely to need renal imaging, yet the standard technique of contrast-enhanced MR angiography with gadolinium may be contraindicated in these patients. This disadvantage and others demonstrate a need to explore non-contrast-enhanced MRA methods [1]. We evaluated one non-contrast enhanced MRI technique which has shown promising results: respiratory-gated In-Flow Inversion Recovery (IFIR) bSSFP [2]. The purpose of this study was to optimize the inversion time (TI) of the images at both 1.5T and 3.0T, and then compare the images quantitatively and qualitatively. The inversion time is critical because it affects the signal of the inflowing arterial blood, the extent of the imaging volume and the background suppression.

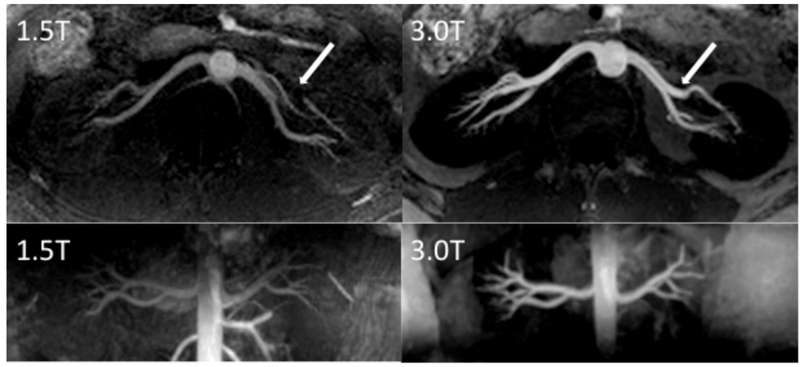

Figure 1. Top: Axial MIP 1.5T vs. 3T. Bottom: Coronal MIP 1.5T vs. 3T. Arrows show higher contrast of renal artery at 3T than at 1.5T. Both have a TI of 800ms.

Methods: ***Acquisition*:** We conducted this study using IFIR, which images inflowing arterial blood during an inversion time of a slab selective inversion (IR) pulse. Venous flow is suppressed by extending the spatially selective IR pulse beyond the imaging slab distally. Axial volumetric data was acquired using the superior pole of the kidneys for alignment with the top of the imaging slab. Five normal healthy volunteers (3F, 2M, age 24-29) were imaged using an 8 channel cardiac coil in GE 1.5T and 3.0T magnets using the following parameters: TE: Min Full (usually 2 ms), TR: Minimum (usually 4 ms), Flip Angle 50°, Matrix 256×256, FOV 30 or 38cm, Slice thickness 3mm, # slices 90, receiver BW 125kHz. ARC parallel imaging (in-plane 2x) and reduced phase-FOV (0.7) were used to decrease scan acquisition time, which was typically 3.5 minutes for each scan [3]. The sequence was respiratory-gated and fat suppression was achieved with a spectrally selective IR pulse. We imaged each volunteer at both magnets non-consecutively at 4 different TI (ms) = 800, 1000, 1200, 1400. ***Analysis*:** First, we determined the optimal TI time for each volunteer by calculating the highest relative contrast at both field strengths. Due to difficult noise calculations in parallel imaging, relative contrast ratios (as opposed to CNR) were measured by dividing the mean signal of the aorta by the mean signal of the kidney medulla. We assumed image noise remained the same for the same volunteer at the same scanner since all parameters were identical except for TI time. After determining that the TI's of 800 and 1000ms gave the highest relative contrast, we had four radiologists rate the images at those two TI times for visualization of delineation of (a) the main renal artery, (b) the intrarenal segmental arteries, and (c) the superior mesenteric artery, on a 5 point scale (1 = not delineated and 5 = sharply delineated over entire course). The significance of the results was analyzed using the Wilcoxon signed-rank test. The 1.5T and 3.0T images were then compared side by side and the radiologists ranked them as better, worse or same.

Table 1: Average Radiologist Ratings showing higher visualization ratings at 3T than 1.5T.

Arteries	TI(ms)	1.5T	3.0T	p-value
Renal	800	4	4.7	0.009
	1000	3.9	4.9	$<10^{-4}$
Intrarenal	800	2.8	3.65	0.002
Segmental	1000	2.7	3.7	0.001
Superior	800	2.85	3.4	0.080
Mesenteric	1000	2.6	3.45	$<10^{-4}$

Table 2: Relative Contrast Ratio averages showing higher average contrast at 3T.

TI (ms)	1.5T	3.0T
800	4.7 ± 2.0	10.8 ± 8.4
1000	3.3 ± 1.5	6.8 ± 3.7
1200	2.5 ± 0.6	3.3 ± 1.0
1400	1.9 ± 0.8	2.8 ± 1.0

Results and Discussion: Figure 1 shows axial MIP (top) and coronal MIP (bottom) images of the same volunteer at 1.5T and 3.0T, demonstrating the increased contrast in the renal and mesenteric arteries at 3.0T than at 1.5T using TI of 800ms (see arrows). Table 1 shows the average ratings at 1.5T and 3.0T amongst the 4 radiologists for each of the 3 categories at the 2 different TI times. Note that the radiologists consistently gave higher visualization ratings for the 3.0T images of the renal, superior mesenteric and segmental intrarenal arteries with significant p-values for all categories except the superior mesenteric artery with a TI of 800ms. Table 2 shows the average relative contrast amongst the 5 volunteers at 1.5T and 3.0T. Note that the highest relative contrast for matching TIs at 1.5T and 3.0T is at a TI of 800ms and that a TI of 1000ms provided the second highest relative contrast, a TI of 1200ms the third highest, and a TI of 1400ms the lowest contrast. When the 1.5T and 3.0T images were then compared side-by-side, the radiologists rated artery delineation in the 3.0T images as better 37 of 40 times, and the same in the other 3 datasets. Besides these results, possible advantages of imaging at 3T include higher resolution at the higher magnetic field strength and more flexibility. The better contrast at 3.0T probably results from the increased T_1 times at 3.0T, which suppress the background longer. These results differ from a previous comparative study of IFIR between 1.5T and 3T in which the radiologists preferred 1.5T [4]. Our results may differ due to our optimization of TI. Our results only apply to healthy subjects; in patients with more complicated and slower blood flow, larger TI times might be more beneficial.

Conclusion: The results of this preliminary volunteer study showed our IFIR method at 3.0T has better relative contrast and visualization of renal and superior mesenteric arteries than at 1.5T.

Acknowledgements: GE Healthcare, NSF Graduate Research Fellowship Program. **References:** **1.** M. Miyazaki and V. S. Lee. Radiol, 248(1):20–43, 2008. **2.** P Young, et al. ISMRM, p.1870 (2009). **3.** PJ Beatty, et al. ISMRM, p. 1749 (2007). **4.** DW Stanley et al. ISMRM p. 1871 (2009).