Non Contrast-Enhanced 3D MR Angiography of Renal Arteries using a Novel Inversion Recovery Steady State Free Precession Technique: Our Initial Experience

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Background: Contrast-enhanced MR angiography (CE-MRA) of the renal arteries has emerged as a commonly accepted technique for the detection of renal artery stenosis due to its greater than 90% sensitivity and specificity in detecting a greater than 50% stenosis (1). However, imaging of the renal arteries without gadolinium chelate is important in some patients in whom intravenous administration of contrast material is not desirable. 3D steady state free precession (SSFP) technique has been shown to be promising in depicting thoracic vessels without the need of contrast media. However, the scan duration was more than 5 minutes (2). Recently, navigator gated cardiac triggered inversion recovery SSFP magnetic resonance angiography (IR-SSFP MRA) has been utilized to image the renal arteries without breath holding or intravenous contrast (3,4). Following further optimization, we have implemented this novel sequence on our 1.5T MR scanner to image and assess the renal arteries.

Objective: To assess the feasibility of non contrast free breathing cardiac triggered IR-SSFP MRA of the renal arteries in clinical patients and to compare the results with conventional high spatial resolution CE-MRA.

Materials and Methods: Our aim is to evaluate 25 patients. Currently, 18 consecutive patients have undergone non contrast-enhanced navigator gated slice selective IR-SSFP MRA and then CE-MRA of the renal arteries on a 1.5T MR scanner. Two patients with transplanted right kidneys underwent only non contrast MRA per physicians' order. Their transplanted renal arteries were excluded from the analysis for comparison with CE-MRA. Data sets were assessed by two radiologists for overall image quality, vessel visibility, motion artifacts, and stenosis evaluation. Parameters of non contrast-enhanced IR-SSFP MRA sequence were: TE 1.57 ms/TR 3.6 ms, 90° flip angle, 340 mm field of view, matrix of 304x304, 88 sections per slab, acquired spatial resolution of 1.1x1.1x1.4 mm^3 (interpolated voxel size, 1.1x1.1x0.8 mm^3), 783 Hz/pixel bandwidth, TI (Inversion delay) 600-1200 ms (depends on patients cardiac output and heart rate), and gating window of 4 mm. For assessment, renal arteries were divided into proximal (PRA), distal (DRA), first order branches (FOB), and first and second accessory branches (AR1 and AR2, respectively). Signal-noise ratio (SNR) and contrast-noise ratio (CNR) of IR-SSFP and CE-MRA sequences were measured. A Wilcoxon signed rank test was used to evaluate any differences in image quality, vessel visibility, and motion artifacts between the two sequences and observers. A paired t-test was used to evaluate any differences of the SNR and CNR between the two sequences. Interobserver agreement between the two readers was determined by calculating Cohen's kappa statistic (k) using a weighted test.

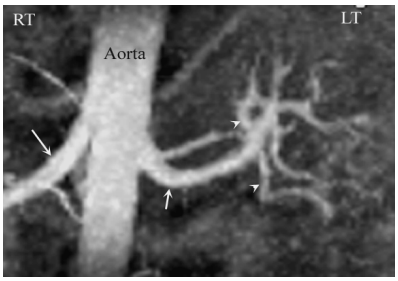

Figure 1. Non contrast-enhanced IR SSFP MRA shows normal appearance of right (white arrow) and left (long white arrow) main renal arteries in a hypertensive patient. First order renal branches (arrowheads) of the left renal artery are shown.

Results: 15 patients successfully underwent both non contrast navigator gated IR-SSFP MRA and CE-MRA. One patient with arrhythmia failed on SSFP MRA, but CE-MRA was successful. A total of 90 segments were assessed, excluding AR1 and AR2. The scan time of this novel sequence was approximately 5 minutes at a heart rate of 75 beats per minute and with a navigator efficiency of 60-70%. For all 15 patients image quality was scored excellent in 12 patients with IR-SSFP MRA versus 10 with CE-MRA for reader 1. Reader 2 rated 12 patients as excellent with IR-SSFP MRA versus 9 with CE-MRA. There was no significant difference in image quality for either reader ($p>0.05$ for both readers). Interobserver agreement for image quality was good (k=0.71). Of the 90 segments evaluated reader 1 rated excellent visibility for 77.8% and 58.9% of segments with IR-SSFP MRA and CE-MRA, respectively ($p<0.01$). Reader 2 rated excellent visibility for 78.9% and 62.2% of segments with IR-SSFP MRA and CE-MRA, respectively ($p<0.01$). Interobserver agreement for visibility was excellent (k=0.81). Reader 1 rated no motion artifacts for 76.7% and 58.9% of segments with IR-SSFP MRA and CE-MRA, respectively ($p<0.01$). Reader 2 rated no motion artifacts for 83.3% and 64.4% of segments with IR-SSFP and CE-MRA, respectively ($p<0.01$). Interobserver agreement for motion artifacts was good (k=0.76). On 4, 1, and 2 patients the left AR1, left AR2, and right AR1, respectively, were visualized with well-defined visibility and mild motion artifacts such that structural pathology could be confidently diagnosed. Using IR-SSFP MRA, both readers identified 3 segments with <50% stenosis (left DRA, n=1; right PRA, n=2), 1 segment with 50-99% stenosis (left FOB, n=1), and 2 totally occluded segments (right DRA, n=1; right FOB, n=1). Two of the segments with <50% stenosis (right PRA, n=2) were not identified on CE-MRA. For the aorta and all renal artery segments both SNR ($p<0.01$) and CNR ($p<0.01$) were significantly better using IR-SSFP MRA when compared to CE-MRA. The mean SNR and CNR of the aorta (at the origin of the main renal arteries) and left and right renal arteries on IR-SSFP MRA are depicted in the table.

Conclusion: Our study demonstrates that non contrast-enhanced 3D MR angiography of the renal arteries is feasible with a navigator gated free breathing cardiac triggered IR-SSFP sequence. This technique provides high image quality and sufficient SNR and CNR for diagnosis of renal artery stenosis. Further clinical studies are warranted to assess the sensitivity and specificity of this sequence in the detection of significant renal artery stenosis compared to catheter angiography or CE-MRA.

Table. The signal-noise ratio (SNR) and contrast-noise ratio (CNR) on non contrast free breathing IR-SSFP MRA sequence

	SNR (mean ± standard deviation)	CNR (mean ± standard deviation)
Aorta (juxta/pararenal)	490.5 ± 177.0	413.9 ± 141.3
Left Renal Artery	475.6 ± 162.0	401.8 ± 129.9
Right Renal Artery	464.1 ± 179.5	392.2 ± 150.0

References:

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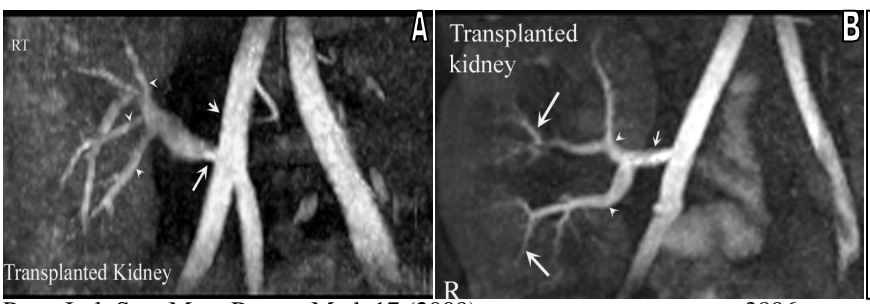

Figure 2. (A) Non contrast IR-SSFP MRA in a patient with transplanted right kidney demonstrates a mild less than 50% luminal narrowing at the anastamosis (long white arrow) with ipsilateral native right distal common iliac artery (short arrow). First order branches (arrowheads) are unremarkable. **(B)** Non contrast IR-SSFP MRA in a patient with transplanted right kidney demonstrates normal transplant renal artery arising from the distal right common iliac artery (short arrow) without a focal significant stenosis. Note normal first order (arrowhead) and intrarenal (long arrows) branches which are well depicted. CE-MRA was not performed for either patient as per physician request.