Non-Contrast Enhanced Renal Angiography Using Multiple Inversion Recovery and Steady-State Free Precession

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Introduction: Renal artery stenosis (RAS) is a well-known cause of renal hypertension and can lead to chronic kidney failure. The recent connection between gadolinium contrast agents and nephrogenic systemic fibrosis (NSF) has prompted renewed interest in non-contrast enhanced MR angiography (NCE MRA) for the diagnosis of RAS, most notably methods based on 3D balanced steady-state free precession (SSFP) [1-3]. The use of an inversion preparatory pulse with SSFP has been proposed to suppress signals from kidney parenchyma and static blood, thereby allowing higher contrast of the renal arteries [1, 2]. Stronger background tissue suppression, including fat, may be achieved by using multiple inversions to concurrently suppress a broad range of T_1's [4, 5]. Previous work showed that this nulling technique offers high contrast in 2D projective renal angiography [5]. In this work, we investigate the use of multiple inversion recovery suppression with 3D balanced SSFP (MIR SSFP) to provide high contrast in renal NCE MRA. Results are compared with balanced SSFP without any magnetization preparation or triggering (plain SSFP), and slab-selective single inversion SSFP (Inv SSFP) [2].

Methods: MIR nulling uses several nonselective inversions timed to minimize the squared sum of blood, fat and muscle signals at a predetermined time after spatial saturation of the imaging region. Meanwhile, inflowing blood maintains its M_z (Fig. 1). The inversions are nonselective to ensure that all imaged blood experiences the same number of inversions [5].

We used an inflow period of 400 ms and four inversions located at 26, 121, 256 and 362 ms after saturation [5]. Plethysmograph triggering was used to place the MIR segment during systole in the renal arteries. Imaging was done using 3D balanced SSFP at the end of the inflow period. Because the static tissue null point occurs for a short period of time, the length of the SSFP train was adjusted to trade off between background suppression and scan time. We found that a train of 64 with the center of k-space sampled at the null point was a good compromise. Mean scan time was 2 min 15 s.

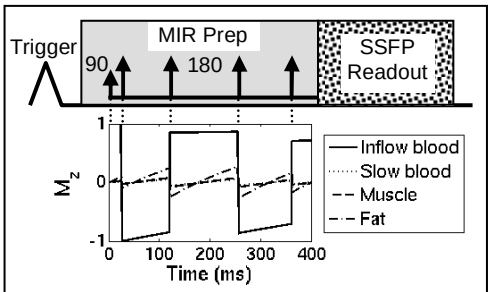

Figure 1. *MIR SSFP sequence. Spatial saturation and four timed inversions null static tissues after a 400 ms inflow period.*

MIR SSFP renal angiography was compared with: 1) plain SSFP (scan time=28 s), and 2) Inv SSFP [2] (inflow period=325 ms, 32 RF excitations per cardiac cycle, mean scan time=2 min 15 s). All sequences used the following parameters: TR/TE=5.4/2.6 ms, flip angle=50°, resolution=1.1×1.1×2.0 mm^3, FOV=28×28×40 cm^3. Studies were conducted on healthy volunteers on a 1.5T GE Signa scanner (40 mT/m, 150 mT/m/ms), and used an 8-channel torso array for reception. Maximum intensity projections (MIPs) were performed on the 3D datasets.

Results and Discussion: Figure 2 shows axial MIPs obtained using the three methods. MIR SSFP demonstrated sharp contrast between the renal arteries and surrounding tissues, and was able to delineate some branch vessels. Fat was mostly suppressed despite a relatively long SSFP readout train (345 ms). Inv SSFP offered a better SNR (~1.5 times) and good contrast, but had higher static tissue signals, which in some cases obscured the distal branches. Plain SSFP required a shorter scan time and provided good SNR. However, it was difficult to differentiate the renal arteries. Motion artifacts were seen in all images, and could be mitigated using navigator-gating. It should be noted that MIR SSFP offers the flexibility to adjust the inflow period while still achieving a good level of background suppression, through re-optimization of the inversion times and / or the number of inversions. This flexibility is not available with plain or Inv SSFP.

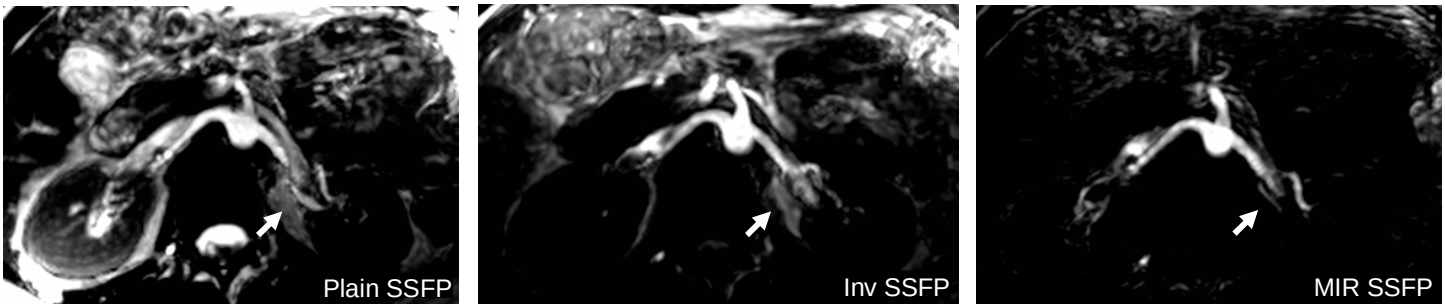

Figure 2. *Axial MIPs obtained using plain SSFP (28 s), Inv SSFP (2 min 15 s), and MIR SSFP (2 min 15 s). MIR SSFP offered excellent contrast, while fat in some cases obscured distal branches in plain and Inv SSFP (arrows). All sequences used parameters: TR/TE=5.4/2.6 ms, flip angle=50°, resolution=1.1×1.1×2.0 mm^3, FOV=28×28×40 cm^3.*

Conclusion: We have demonstrated that MIR SSFP offers excellent contrast in renal angiography without administering contrast agents. A MIR preparation with four inversions was used to simultaneously suppress slow blood, fat and muscle at readout. The length of the readout SSFP train was adjusted to trade off between background tissue nulling level and scan time.

References:

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