

3D Non-Contrast MRA of Lower Extremities Using Balanced SSFP with Flow-Sensitive Dephasing (FSD) at 3T

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INTRODUCTION

Flow-sensitive dephasing (FSD) prepared balanced steady state free precession (FSD-bSSFP) has been proposed as a non-contrast MRA technique for the lower extremities at 1.5T [1,2]. However, its application at higher magnetic fields is hindered by poor B0 and B1 homogeneities [3]. As a result, the background signal cannot be completely suppressed. In this work, we investigated the performance of B1-insensitive adiabatic RF pulses [4] to improve non-contrast MRA with FSD-bSSFP at 3T.

METHOD

The proposed FSD preparation module consists of three B1-insensitive rotation (BIR-4) RF pulses (Fig. 1): (1) a reverse adiabatic half passage (rAHP) pulse, (2) a fast passage (AFP) pulse, and (3) an adiabatic half passage (AHP) pulse [4]. The same modulation function is used to generate AFP and AHP pulses. When an rAHP pulse is applied along the x axis (Fig.1), it tips the magnetization of both static and moving spins into the transverse plane. The bipolar gradients [1, 2] with a first-order gradient moment of m1 are then applied along the blood flow direction to dephase the moving spins. Next, an AHP pulse applied along the (-x) axis returns the static spin magnetization and any residual moving spin magnetization (if they satisfy the adiabatic condition) to the longitudinal axis. Finally, the transverse magnetization that remains after the FSD preparation are crushed by large gradients (amplitude = 8 mT/m and duration = 5.4 ms) along the three directions. To reduce T2 decay intrinsic to the FSD preparation module, maximum gradient slew rate and amplitude are used to minimize the duration of bipolar gradients. The introduction of bipolar gradients extends the duration of the FSD module from 10.3 ms to 14.9 ms. It is also important to note that the flip angles of the bSSFP sequence must be reduced to compensate for the SAR increase caused by BIR-4 pulses in FSD preparation.

3D ECG-triggered FSD-prepared FSD-bSSFP was implemented on a 3T Siemens MRI scanner (Trio, Siemens, Erlangen, Germany). A 16-channel peripheral matrix coil anteriorly and laterally and spine coil posteriorly were used for image acquisition. Oblique coronal partitions with fat saturation were acquired to cover the left and right lower leg calves: image matrix=384x328 mm²; slice thickness=1.3 mm; FOV=380x450 mm²; IPAT (phase direction) = 3; partial Fourier along slice direction = 6/8; TE=1.57 ms; flip angle = 20°; first gradient moment set to 40 mT·ms²/m and applied along the head-foot direction; TR=1 R-R interval; receiver bandwidth=1000 Hz/pixel; and 2 shots per partition. Total acquisition time was approximately 3-4 minutes. Before the MRA acquisition, a through-plane phase contrast imaging of the popliteal arteries was performed to measure the arterial velocity curve, and identify optimal systolic and diastolic trigger delays. Bright-blood images were acquired with the trigger delay set to late diastole while black-blood images were acquired with the trigger delay set to peak systole. Maximum intensity projection (MIP) of the subtracted MRA images was generated for review. The 3D FSD-bSSFP MRA sequence using BIR-4 was first evaluated on a stationary phantom using the same acquisition protocol as for *in vivo* studies (with artificial ECG gating). An average background signal suppression ratio, defined as 1 - (MIP of subtraction images)/(MIP of source images), was calculated measuring signal over the whole phantom. Results were compared with FSD with regular hard RF pulses (180° using either single or composite hard RF pulses). For *in vivo* studies, three healthy volunteers were recruited and provided informed written consent.

RESULTS AND DISCUSSION

Fig. 2 shows the phantom result for background suppression check. By using BIR-4 RF pulses, post subtraction signal is well suppressed, with an average background signal suppression ratio of 96.8% (Fig. 2c). By comparison, FSD preparation with regular hard RF pulses could not eliminate the background to within 12.8% of the original value (Fig. 2b). Figure 3 shows the MRA of a representative subject. The arteries are clearly depicted in both lower legs. bSSFP banding artifacts from B0 inhomogeneity appear along the edge, which may interfere with clinical interpretation, for example, affecting the right popliteal artery in this case. Overlap of a superior station would ensure diagnostic interpretation. All volunteers showed similar results.

CONCLUSION

FSD preparation with BIR-4 is less B1-sensitive than with conventional hard RF pulses, thus providing better background signal suppression and more reliable MRA images at 3T. Clinical studies are required to systematically evaluate its performance in patients with arterial disease.

Acknowledgements: Funding support by NIH grant HL092439. **References:** [1] Fan Z et al., MRM 2009; 62. [2] Korosec FR et al., MRM 1993; 30:704. [3] Mugler JP et al., JMRI 1991; 1:731. [4] Nezafat R et al. MRM 2009; 61:1326.

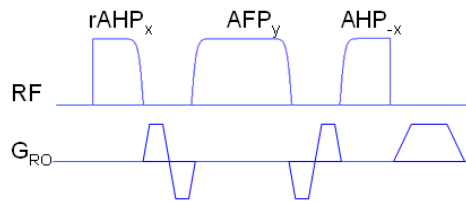


Fig. 1. Pulse diagram of the FSD module using BIR-4.

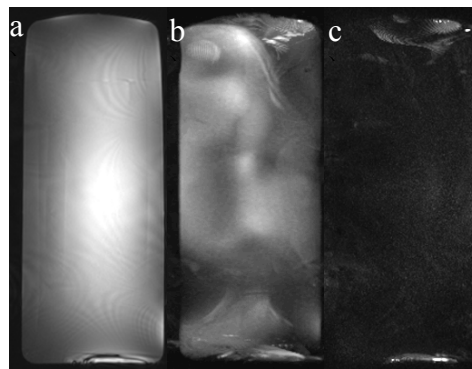


Fig. 2. Phantom test. a) Raw image from BIR-4; b) MIP of subtraction images from acquisition using regular hard RF pulses; c) MIP from acquisition using BIR-4 pulses.

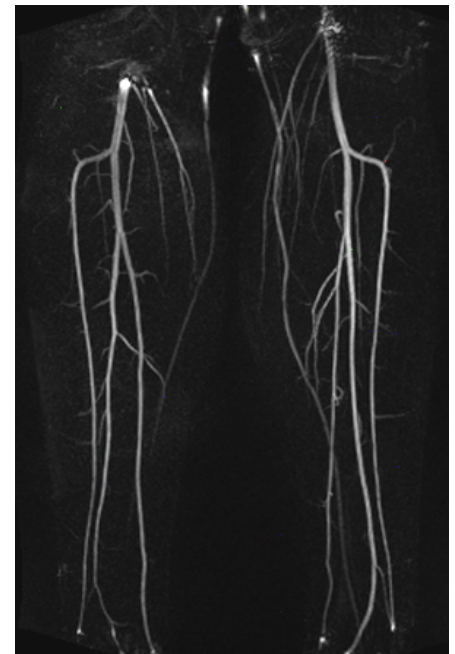


Fig. 3. MRA of the calves demonstrates the popliteal, tibioperoneal, peroneal, and anterior and posterior tibial arteries with good background signal suppression.