Optimization of the First-Order Gradient Moment for Flow-Sensitive Dephasing Magnetization-Prepared 3D Noncontrast MRA

Z. Fan1, 2, X. Zhou1, X. Bi1, S. Zuehlsdorff1, R. Dharmakumar1, 2, J. Carr1, and D. Li1, 2
1Cedars-Sinai Medical Center, Los Angeles, California, United States, 2Northwestern University, Chicago, Illinois, United States, 3Siemens Healthcare, Chicago, Illinois, United States

Introduction: ECG-triggered flow-sensitive dephasing (FSD) prepared 3D balanced SSFP was recently developed as a noncontrast approach to peripheral MRA [1]. Flow sensitization imparted by the FSD preparation is essential for the technique, and its strength can be measured by the first-order gradient moment, \( m_1 \). Incomplete delineation of arterial segments may result from a suboptimal \( m_1 \). The optimal \( m_1 \) however, is subject and artery specific [2, 3]. A 2D m\(_1\)-scouting method has previously been proposed to rapidly assess a range of \( m_1 \) values for their effectiveness in blood signal suppression [4]. The aim of this work was to systematically investigate the utility of this scouting method for improving image quality of 3D FSD MRA.

Materials and Methods: Sequence A 2D pulse sequence for \( m_1\)-scouting (Fig. 1) was implemented based on FSD-prepared bSSFP [4]. Eleven measurements were obtained in a single transverse slice. Incremental \( m_1 \) values as defined by starting \( m_1 \) value (\( m_{1,\text{start}} \)) and step size (\( m_{1,\text{step}} \)) were used. FSD gradients applied in the slice-select direction only coincided with the principal direction of flow. Segmented acquisition was performed every second or third (for short R-R intervals) heartbeat to eliminate the potential interference of blood-suppressing performance from successive \( m_1 \)’s.

- Subject and Hardware This IRB approved study included 10 healthy subjects (7 males, 21-27 yo) and 1 patient (female, 89 yo) with peripheral artery disease. Data were collected on a 1.5T MR system (MAGNETOM Avanto, Siemens, Erlangen, Germany) equipped with a 16-element peripheral matrix coil and spine coil.

- FSD MRA Bilateral knees and calves, including the popliteal arteries, anterior and posterior tibial arteries, tibioperoneal trunk, and peroneal arteries, were covered with an oblique coronal acquisition orientation. (a) An “Empirical Scan” was first performed using an \( m_1 \) of 35 mT ms\(^{-1}\) m, an empirical value used in previous work [1]. (b) An “Optimized Scan” was performed for each leg with an \( m_1\)-scouting optimized \( m_1 \) (\( m_{1,\text{opt}} \)) of 5/5 mT ms\(^{-1}\) m in healthy subjects, 15/10 mT ms\(^{-1}\) m in patients if it was different than the empirical value. Parameters of 2D \( m_1\)-scouting (3D FSD MRA): resolution 0.94x0.94x5 (0.94x0.94x0.94) mm\(^3\), TE/TR 1.6/3.3 (2.0/4.0) ms, 46 (60) segments/shot, flip angle 90\(^\circ\), GRAPPA factor 2. Additionally, FSD MRA using a set of five \( m_1 \) values (including the optimal value) that have been scouted was obtained in two of the ten healthy subjects for demonstration purposes.

- Contrast-Enhanced MRA CE-MRA was performed in the patient using our institution’s routine protocol as described in previous work [1].

Results: 2D scout imaging time was 14 min. Among 11 subjects, different optimal \( m_1 \) values on the right and left legs. Sixteen out of 22 legs (72.7%) were judged to have an optimal \( m_1 \) value different than 35 mT ms\(^{-1}\) m. With the optimization procedure, the relative (due to parallel imaging) arterial SNR, artery-background CNR, and artery-vein CNR on resultant MRA’s were significantly increased by 20.8%, 22.3%, and 24.0%, respectively (\( p < 0.05 \). Fig. 2 shows a set of MRA’s from a healthy volunteer where 25 mT ms\(^{-1}\) m, an optimal \( m_1 \) determined from 2D scouting, provided the sharpest depiction of arterial segments without signal contamination from venous blood and background tissues. Fig. 3 shows the MRA’s from the PAD patient who had different optimal \( m_1 \) in the left/right legs. Small collateral vessels were better depicted with those optimal \( m_1 \)’s compared to using the empirical \( m_1 \).

Discussion and Conclusion: With optimized flow sensitization, significant increases in SNR/CNR on MRA’s were obtained, suggesting the necessity of the procedure. Such an improvement would potentially help enhance diagnostic confidence. We believe that an optimal \( m_1 \) will minimize the likelihood that an arterial stenosis or occlusion is overestimated. A clinical study is currently underway to verify the efficacy of this method on disease evaluation.