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

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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 [2, 3]. 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 ($m_{1,start}$) and step size ($m_{1,step}$) 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^2/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 ($m_{1,start}/m_{1,step}$ of 5/5 mT•ms^2/m in healthy subjects, 15/10 mT•ms^2/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° (81°), 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.

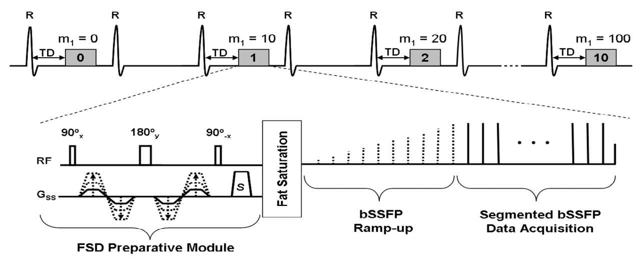

Fig. 1. Sequence diagram of 2D m_1-scouting imaging. A total of 11 measurements were obtained during a single transverse scan using m_1 = 0, 10, 20, …, 100 mT•ms^2/m (User-specified)

- 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 <1 min. Four among 11 subjects showed 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^2/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^2/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.

References: 1. Fan Z, et al. MRM 2009;62:1523. 2. Nguyen TD, et al. JMRI 2008;28:1092. 3. Haacke EM, et al. New York: Wiley-Liss;1999, pp 673. 4. Fan Z, et al. ISMRM 2010;1410.

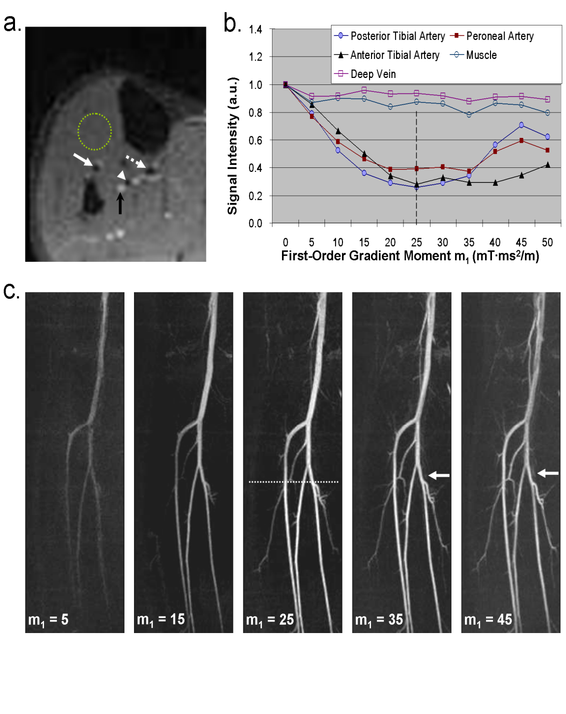

Fig 2. From the m_1-scouting images (a) (location marked by dotted line in (c)), SI from three arteries (white arrows and arrow head), deep vein (black arrow), and muscle (dotted circle) is measured to provide Signal-m_1 curves (b). The curves show that m_1 = 25 mT•ms^2/m (marked by dashed line) can suppress the arterial blood SI by up to 75%, with little sacrifice of SI from the vein and muscle. MRA (c) using this value is deemed optimal because of sharpest depiction of arterial segments without signal contamination from venous blood and background tissues

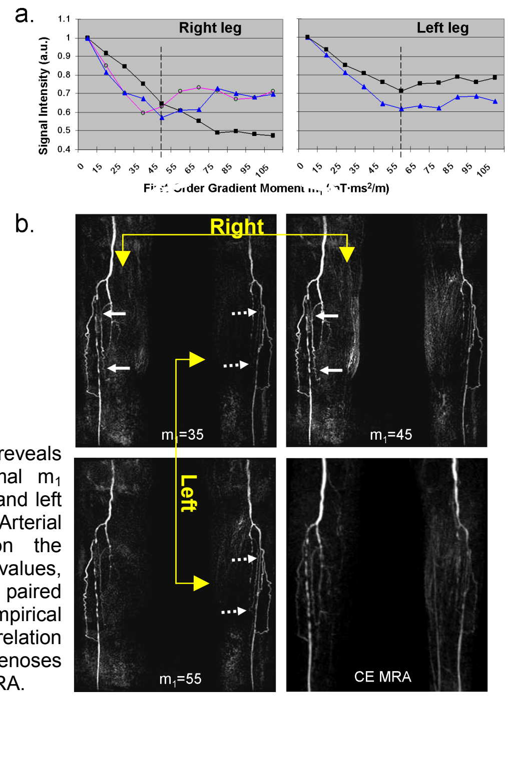

Fig 3. The m_1-scouting procedure (a) reveals that the patient has different optimal m_1 (marked by dashed line) on the right and left legs, namely 45 and 55 mT•ms^2/m. Arterial segments exhibit higher signal on the corresponding legs when using these values, as compared to (paired solid arrows, paired dashed arrows) the case using the empirical m_1. Furthermore, there is excellent correlation in depiction of occlusion and stenoses between optimal FSD MRA and CE MRA.