

Noncontrast MRA of Distal Lower Extremities Using Flow-Sensitized Dephasing Prepared SSFP

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Introduction: Peripheral arterial disease (PAD) is a major cause of diminished functional capacity and quality of life in a large portion of western populations. While 3D contrast-enhanced (CE) MRA is becoming the method of choice for clinical PAD examinations, safety concerns with contrast administration in patients with renal insufficiency have triggered a renaissance of non-contrast MRA (NC-MRA). NC-MRA strategies employing 3D half-Fourier FSE [1] or SSFP [2] have shown great promise but various challenges remain. The present work aimed to develop a new NC-MRA method in lower extremities based on flow-sensitized dephasing (FSD)-prepared SSFP and to optimize the FSD strength for high arterial SNR and artery-vein CNR.

Materials and Methods: The proposed NC-MRA method acquires a bright-artery scan using ECG-triggered SSFP and a dark-artery scan using ECG-triggered, FSD-prepared SSFP [3]. Subtraction of the two scans results in bright arteries and suppression of the background and veins. The FSD module consists of a 90°_x - 180°_y - 90°_x pulse series and bipolar gradients before and after the 180° pulse (Fig. 1). It suppresses signals from moving spins such as arterial blood via intravoxel dephasing. With laminar flow, more flowing-spin phase dispersion is induced by a higher first-order gradient moment, m_1 , or higher flow velocity. Because of the markedly different flow velocities in arteries and veins during systole, an optimal m_1 will result in complete arterial blood signal loss while having little effect on the venous blood in the dark-artery scan. Bright-artery scan is acquired in diastole to minimize flow artifacts with SSFP, achieving bright blood signal in both arteries and veins.

Nine healthy subjects and two PAD patients were imaged at 1.5T (MAGNETOM Avanto, Siemens) using a 16-element peripheral matrix coil and spine coils. Phase-contrast flow imaging was first performed above the popliteal trifurcation to derive the arterial flow peak time T . In each healthy subject, 5 subtraction imaging were performed, with each one including a bright-artery scan acquired at mid-diastole and a dark-artery scan with a trigger delay time of $\sim T$, gradient duration $\delta = 1.2$ ms, and FSD gradient strength G equal to one of 5, 10, 15, 20, and 25 mT/m. For each FSD gradient strength, a subtraction data set was created, and two radiologists reviewed its maximum intensity projections (MIP's) for diagnostic quality by giving a score in consensus to each of the 3 portions (superior to inferior) of calf-arteries (1, poor; 2, fair; 3, good; 4, excellent) and adding them together for each leg (full score: 12). Arterial and venous signal intensities were measured from 6 ROI's, respectively, located at the middle portions of the major arteries and neighboring veins on subtraction 3D data sets and then averaged for individual legs. Noise level was measured as an average standard deviation from 6 ROI's in air space between the two legs. Two patients underwent NC-MRA ($G = 15$ mT/m, $\delta = 1.2$ ms) prior to clinical CE-MRA. SSFP readout parameters included: TE/TR = 1.9/3.8 ms, coronal acquisition, centric phasing-encoding, 3 shots/partition, FOV = 400x311x67 mm³, matrix = 432x336x72, spectral-selective fat sat, bandwidth = 965 Hz/pixel, GRAPPA parallel imaging factor = 2, flip angle = 90° , acquisition time = ~ 3 min/scan.

Results: As FSD gradient strength increased from 5 to 25mT/m, major branches of the calf arteries were depicted, however more veins also appeared, contaminating arterial delineation in MIP's (Fig. 2). Both arterial SNR and image score were significantly affected by gradient strength ($p < 0.05$) according to generalized linear model test (GLM) and Friedman test, respectively. Gradient strength had also substantial effect on artery-vein CNR, although it is not significant ($p = 0.068$, GLM test). Note that all five FSD gradient strengths tested herein were able to produce an image with average diagnostic quality of at least 3 on a 4-point scale. $G=10$ mT/m generated the highest arterial SNR, artery-vein CNR, and image score (Fig. 3). In the two patients, NC-MRA detected a significant stenosis as confirmed by CE-MRA (Fig. 4).

Discussion and Conclusions: The results indicate that $G = 10$ mT/m, i.e. $m_1 = 34.8$ mTms²/m, can achieve an optimal m_1 for healthy volunteers. Further optimization of the technique on PAD patients is warranted. The flexibility of choice on the FSD gradient strength and direction allows to adapt the parameters to individual physiological conditions in patients to achieve optimal results. It is therefore anticipated that this technique could be applied to other vascular territories with appropriate choices of m_1 .

References: 1. Miyazaki M, et al. Radiology 227:890 (2003). 2. Stafford R, et al. MRM 59:430 (2008). 3. Koktzoglou I, et al. JCMR 9:33 (2007).

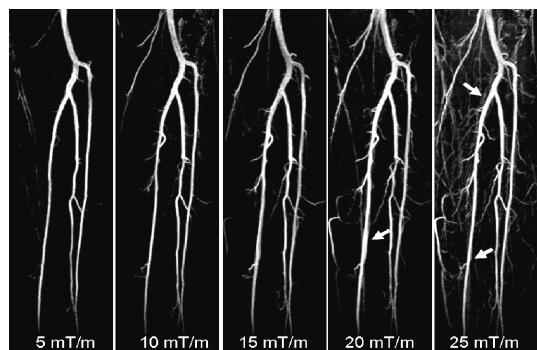


Fig. 2. MIP MRA. As the FSD gradient increased, more branch arteries are depicted, but more veins appeared as well (arrows).

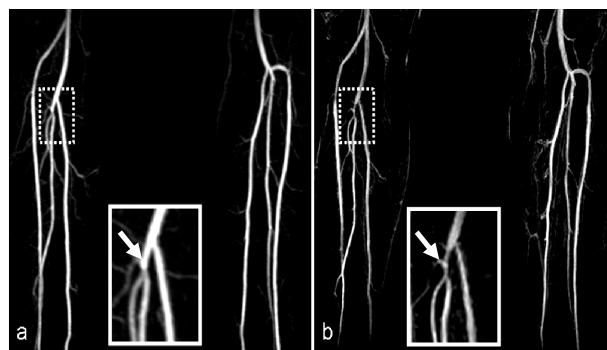


Fig. 4. Both CE-MRA (a) and NC-MRA (b) detected a significant stenosis (arrows). Note that NC-MRA has sharper artery delineation due to higher and isotropic spatial resolution.

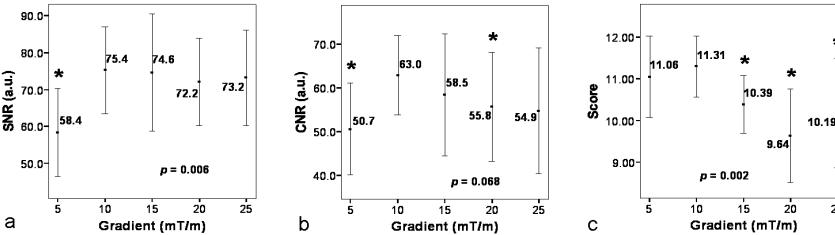


Fig. 3. FSD gradient strength has significant effect on arterial SNR and image quality score, and also substantial effect on artery-vein CNR (p -value shown in each panel). All five gradient strengths were able to generate MRA images with satisfactory diagnostic quality. $G=10$ mT/m resulted in the highest SNR, CNR, and image score (* indicates significant difference from other groups using paired t-test. Significant level) was set at 0.05).