Comparison of 3D non-contrast enhanced foot MR angiography using steady-state free precession with single and multi-directional FSD modules preparation

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Introduction Three-dimensional (3D) non-contrast enhanced MR angiography (NCE-MRA) using flow-sensitive dephasing (FSD) prepared steady-state free precession (SSFP) had proved a promising strategy for evaluation of peripheral vasculature without the use of gadolinium-based contrast agent [1-3]. Several advantages of the technique over other NCE-MRA methods were detailed in a previous work including high isotropic spatial resolution and a sufficiently clean background [4]. The magnetization preparation with FSD gradients was used for the blood signal suppression with advantages of flow-independence. It could be flexibly configured in both direction and strength so that multidirectional flow suppression was feasible. Applying FSD gradients in two or three directions could improve the image quality than in only one direction. However, there was no existed study to evaluate the effect of NCE-MRA with multi-directional FSD modules preparation on feet. The purpose of this study was to compare the image quality of pedal arteries acquired from the NCE-MRA technique with single directional and two-directional FSD modules preparation, respectively.

Methods This prospective study was approved by the hospital institutional review board. Written informed consents were obtained from all participants. 35 subjects comprised of 32 healthy volunteers (19 male, age range 24-77 years, mean age, 45 years) with no history of arterial diseases or arrhythmia and 3 patients (2 male, age range 45-72 years, mean age, 59 years) with type II diabetes were examined on a 1.5T MR scanner (MAGNETOM Avanto, Siemens healthcare, Germany). A cylindrically shaped 12-element phased-array head coil was used for signal reception. All subjects were placed feet first and in a supine position. NCE-MRA images of pedal arteries were acquired using FSD prepared SSFP sequence with electrocardiographic (ECG) trigger. The imaging slab was oriented in the oblique coronal plane with readout in the superior-inferior direction and phase-encoding in the left-right direction. The first-order moment (m1) value of the FSD gradients derived from a scout approach (120～170 mT•ms2) [5] were applied in only readout direction and in both readout and partition-encoding (anterior-posterior) direction, respectively. Identical imaging parameters included: TR/TE =3.9 ms/1.8 ms, flip angle = 90°, field of view = 300 × 200 × approximately 80 - 90 mm3, voxel size = 0.9 × 0.9 × 0.9 mm^3 without interpolation, receiver bandwidth = 965 Hz/pixel, GRAPPA acceleration factor = 2. Maximum intensity projection (MIP) images were reconstructed for assessing image quality on five segments (dorsal artery, lateral plantar artery, medial plantar artery, pedal arch, and metatarsal arteries) by two experienced readers in consensus on a four point scale [6]. Cross sectional plane of the arterial segment were created for calculation of arterial blood signal-to-noise ratio (SNR), artery-tissue contrast-to-noise ratio (CNR), and vessel sharpness on three main arterial segments (dorsal artery, lateral plantar artery, and pedal arch) according to a previously described method [7]. The results were presented as mean ± SD and analyzed statistically using IBM SPSS (version 19.0, Chicago, IL). The image quality scores, SNR, CNR, and vessel sharpness measured from the two NCE-MRA techniques respectively were compared using a nonparametric Wilcoxon signed rank test. A p value less than 0.05 was considered to indicate statistical significance.

Results All examinations were performed successfully and were well tolerated by all subjects. A total of 350 calf arterial segments were obtained in the 35 subjects. The mean acquisition time for pedal arteries was 5.5 ± 1.2 and 5.4 ±1.3 minutes for SSFP with only one directional and two directional FSD modules preparation, respectively, and the difference was no significant (P>0.05). No significant difference existed in number of diagnostic arterial segments (327[93.43%] vs. 330[94.29%], respectively, p=0.64), SNR, CNR, and vessel sharpness of NCE-MRA images acquired from SSFP sequence with one FSD module applied in only readout direction and two FSD modules applied in both readout and partition-encoding directions (Figure 1). The image quality of NCE-MRA with single directional FSD module preparation was slightly higher than that with two directional FSD modules preparation (Figure 1). However, pedal arch not displayed completely in full length in some images acquired with single directional FSD module preparation was delineated well in images acquired with two directional FSD modules preparation (Figure 2).

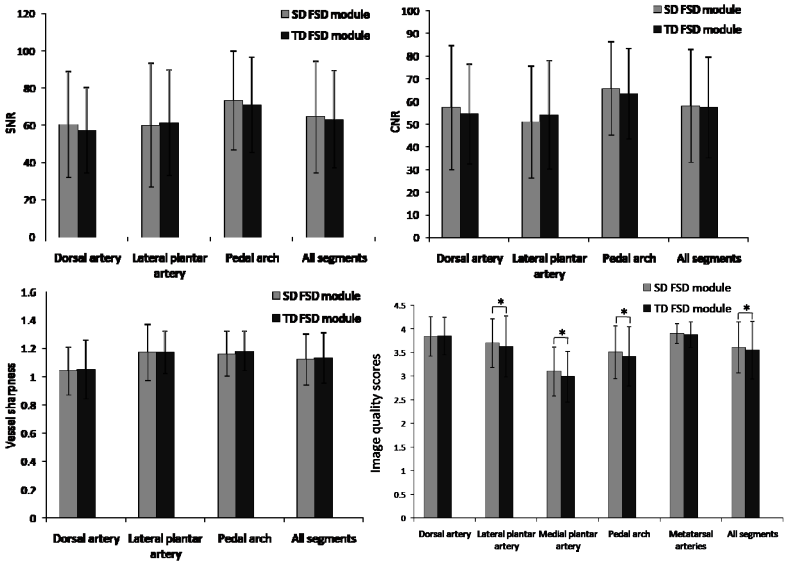

Figure 1 Comparison of SNR, CNR, vessel sharpness, and image quality scores between single directional (SD) and two directional (TD) FSD modules in three main arterial segments of the feet. Each column represents average measurements and error is shown as standard deviation. Asterisks indicated significant difference (P < 0.05).

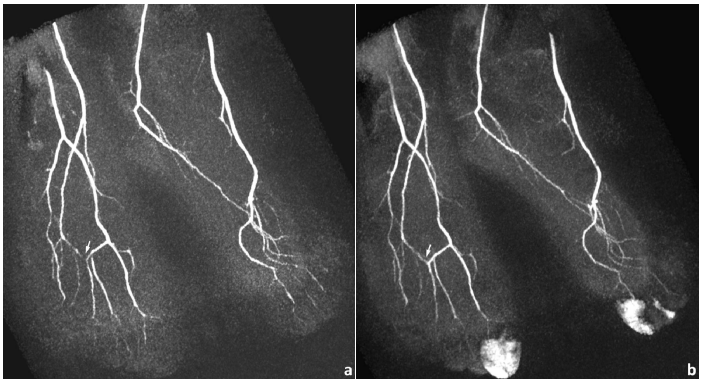

Figure 2 MIP images of SSFP with single directional (left) and two directional FSD modules (right) preparation of the pedal arteries in a 28-year-old man. A false stenosis caused by signal loss is seen at the right pedal arch (arrow) on the MIP image of SSFP with FSD module applied in only superior-inferior direction.

Discussions Both single directional and two directional FSD modules preparation caused similarly SNR, CNR, and vessel sharpness of pedal arteries, but images acquired with two directional FSD modules preparation showed better depiction of pedal arch due to the adding application of FSD module in anterior-posterior direction. The slightly lower image quality score of SSFP with two directional FSD modules preparation was due to the soft tissue contamination on toes (Figure 2). However, it didn't affect the depiction of arteries.

Conclusion NCE-MRA with FSD-prepared SSFP was enhanced in the depiction of multi-directional flow by applying a two directional FSD module preparation.

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