Non-contrast enhanced MR angiography in the calf: A comparison between Flow-sensitive dephasing prepared steady-state free precession and quiescent-interval single-shot in patients with diabetes

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Introduction Two non-contrast enhanced magnetic resonance angiography (NCE-MRA) techniques based on steady-state free precession (SSFP), namely flow-sensitive dephasing (FSD) [1] and quiescent-interval single-shot (QISS) [2], have been proposed to achieve higher signal to noise ratio (SNR) of arterial blood and less flow artifacts existed inherently in TSE-based NCE-MRA [3-4]. FSD using a 3D acquisition scheme allows isotropic high spatial resolution and benefits the visualization of stenosis lesions, but requires tune-up in imaging parameters on a case-by-case basis. QISS is dramatically simplified in procedure, yet its slice resolution is relatively low due to the two-dimensional (2D) acquisition scheme. In several recent clinical studies, both techniques have demonstrated great potential for clinical applications in detecting arterial disease in the lower extremities [5-6]. To our knowledge, however, no study has been performed to compare the potential benefits and drawbacks of the two NCE-MRA techniques. The purpose of this study was to compare the image quality and diagnostic accuracy of the FSD and QISS techniques for the detection of lower extremity arterial stenosis in a diabetic patient cohort, using conventional high resolution contrast-enhanced MRA (CE-MRA) as the reference standard.

Methods Twenty six patients (16 men; mean age, 59 years; age range, 34-79 years) with type II diabetes diagnosed according to 2006 WHO diabetes criteria underwent lower extremity NCE-MRA using FSD (TR/TE =468.4 ms/1.6 ms, echo spacing = 3.5ms, oblique coronal acquisition, flip angle = 90°, FOV = 400 × 320 × 60-70 mm^3, voxel size = 0.9 × 0.9 × 0.9 mm^3, receiver bandwidth = 965 Hz/pixel, GRAPPA parallel acceleration factor 2 in the phase-encoding direction, 60 lines per heartbeat.) and QISS (TR/TE = 708.1 /1.4 ms, echo spacing = 3.4ms, quiescent interval = 228ms, inversion time = 350ms, flip angle = 90°, trigger delay = 100ms, 2.4mm effective slice thickness (3mm with 0.6mm overlap), GRAPPA parallel acceleration factor = 2, bandwidth = 695 Hz/pixel, number of averages = 1, full Fourier sampling, and fat suppression, matrix = 560×800, field of view (FOV) = 280×400mm (in-plane spatial resolution of 0.5mm)), respectively, followed by CE-MRA on a 1.5T MR system (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany). Quantitative evaluation (arterial blood signal-to-noise ratio [SNR], artery-tissue contrast-to-noise ratio [CNR], and vessel sharpness) based on a previously described method [7] and qualitative evaluation (image quality, stenosis scores, and diagnostic accuracy for detecting more than 50% arterial stenosis based on the arterial segments of diagnostic image quality) [8] were performed for the two NCE-MRA techniques, independently, by two reviewers on consensus and were statistically compared using CE-MRA as the reference standard.

Results All examinations were performed successfully and a total of 153 calf arterial segments were obtained in the 26 patients with 51 legs. FSD and QISS showed no significant difference in the number of diagnostic arterial segments (151 [98%] vs. 147 [96%], respectively, P>0.05). The image quality of FSD was higher than that of QISS in the peroneal artery (3.55 ± 0.46 vs. 3.30 ± 0.81, P<0.05) and posterior tibial artery (3.58 ± 0.58 vs. 3.43 ± 0.74, P<0.05), but no significant difference in the anterior tibial artery (3.37 ± 0.62 vs. 3.23 ± 0.82, P>0.05). Figure 1 demonstrated that FSD allowed higher spatial resolution and SNR for depicting calf arteries and detecting arterial stenosis. The arterial SNR and artery-tissue CNR of FSD were higher than those of QISS (P<0.01), while FSD showed comparable vessel sharpness compared with QISS (P>0.05) (Figure 2). The time efficiency of SNR and CNR of FSD with only dark and bright blood scan was higher than that of QISS, but when adding the times for FSD-related scout scans, FSD showed no significant difference with QISS (Figure 3). No significant difference was found when the average mean stenosis scores were compared between any two of the three techniques (p>0.05). There was no difference in sensitivity (95% vs. 93%, P>0.05) or negative predictive value (98% vs. 97%, P>0.05) between FSD and QISS for detecting more than 50% stenosis, but FSD showed higher specificities (99% vs. 92%, P<0.05) and diagnostic accuracy (98% vs. 92%, P<0.05).

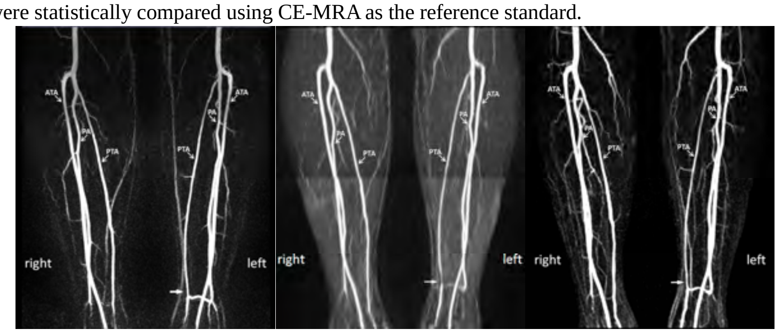

Figure 1. MIP images of FSD (left) and CE-MRA (right) of the calf arteries show no significant stenosis in the bilateral calf arteries in a 54-year-old woman with diabetes. Soft tissue artifacts and a false stenosis caused by signal loss are seen at the left distal peroneal artery (arrow) on the MIP image of QISS (middle).

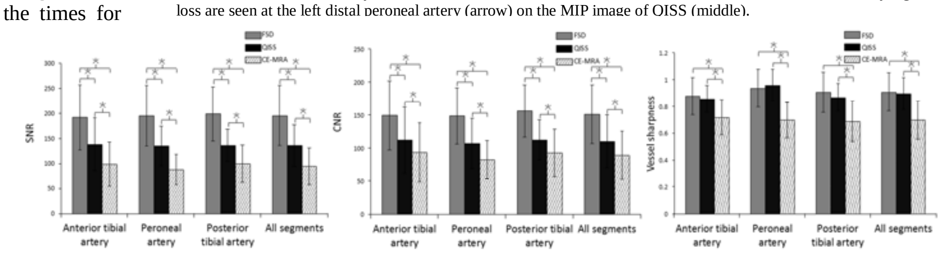

Figure 2. Comparison of SNR, CNR, and vessel sharpness between FSD, QISS, and CE-MRA in three arterial segments of the calf. Each column represents average measurements and error is shown as standard deviation. Asterisks indicated significant difference (P < 0.05).

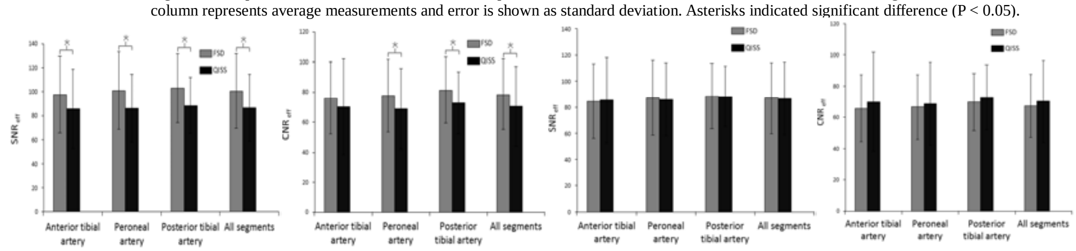

Figure 3. Comparison of the time efficiency of SNR (SNR eff) and CNR (CNR eff) between QISS and FSD with only dark and bright blood scan (a, b) or adding the phase-contrast and m1-scout scan (c, d)) in three arterial segments of the calf. The Each column represents average measurements and error is shown as standard deviation. Asterisks indicated significant difference (P < 0.05).

Discussions Both FSD and QISS allow satisfactory image quality with high SNR and CNR for the delineation of calf arteries, and comparable diagnostic performance for the evaluation arterial stenosis compared with CE-MRA without the use of gadolinium-based contrast agent. Both the NCE-MRA techniques have high negative predictive value for detecting significant stenosis, suggesting that the techniques could be a reliable screening tool for excluding infragenual significant arterial stenosis. Compared to QISS, FSD showed better depiction of small collaterals and higher specificity for assessing severity of arterial stenosis, likely due to its isotropic submillimeter spatial resolution and higher arterial blood SNR/CNR. On the other hand, QISS is easier to use and less time-consuming due to no needs for prescription of imaging volume and searching for optimal imaging parameters related to the black blood acquisition.

Conclusion Both FSD and QISS had similarly high sensitivity and negative predictive value for detecting more than 50% stenosis of calf arteries, but FSD showed higher diagnostic specificity and better depiction of arterial lesions due to its isotropic submillimeter spatial resolution. QISS could be a choice for rapidly screening arterial disease of lower extremity being an easier to use and less time-consuming technique.

References[1] Fan Z, et al., Magn Reson Med, 62(6):1523-32, 2009. [2] Edelman RR, et al., Magn Reson Med, 63(4):951-8, 2010. [3] Wheaton AJ, et al., J Magn Reson Imaging, 36(2):286-304, 2012. [4] Lim RP, et al., Radiology, 267(1):293-304, 2013. [5] Sheehan JJ, et al., Radiology, 259(1):248-256, 2011. [6] Hodnett PA, et al., Radiology, 260(1):282-93, 2011. [7] Li D, et al., Radiology, 219(1):270-7, 2001. [8] Hodnett PA, et al., AJR Am J Roentgenol, 197(6):1466-73, 2011.