Clinical evaluation of peripheral non-contrast enhanced MR angiography (NCE-MRA) using steady-state free precession (SSFP) and flow sensitive dephasing (FSD) in diabetes

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Introduction: Contrast-enhanced MR angiography (CE-MRA) is widely used in clinical practice for non-invasive evaluation of peripheral arteries. However, the use of gadolinium-based agents has been limited in patients with renal insufficiency because of the concerns regarding nephrogenic systemic fibrosis. Furthermore, short contrast first-pass window in arteries often limits imaging coverage or spatial resolution and venous contamination may be present at distal run-off vessels. Recently, a novel peripheral NCE-MRA technique using steady-state free precession (SSFP) and flow-sensitive dephasing (FSD) has demonstrated potential clinical value for visualizing peripheral arteries [1].The purpose of this study was to prospectively assess the diagnostic performance of the technique in patients with diabetes.

Methods: Forty-five consecutive patients with diabetes (type Ⅰ in one and type Ⅱ in 44) underwent CE-MRA and NCE-MRA in calf and foot on a 1.5T MR system (Avanto, Siemens). A 12-element body and head coil were used for calf and pedal arteries acquisition, respectively. CE-MRA was performed using care-bolus high-resolution MRA with a spatial resolution of 1.0×1.0×1.0 mm^3. NCE-MRA was performed prior to CE-MRA during the same imaging session by using an ECG-triggered 3D segmented SSFP with FSD magnetization preparation. Imaging parameters included: TE/TR =1.9/3.8 ms, receiver bandwidth = 965 Hz/pixel, FOV = 400×320×60 mm^3 for calf and 300×200×90 mm^3 for feet, voxel size = 0.9×0.9×0.9 mm^3, flip angle = 90°, GRAPPA acceleration factor = 2, acquisition time = 2～4 min per scan, depending on the heart rates. The first-order gradient moments of the FSD gradient were individually optimized using a scout approach (25～45 $mTms^2$ for calf and 100～150 $mTms^2$ for foot). Maximum-intensity projections of the entire volume were created for image analysis. For CE-MRA, two experienced radiologists assessed in consensus the image quality on a 1-4 point scale (2 or more was defined as diagnostic) and presence of significant arterial stenosis（≥50%）in three calf arterial segments (anterior tibial artery, posterior tibial artery, and peroneal artery) and four foot arterial segments (dorsal pedal artery, lateral plantar artery, medial plantar artery, and pedal arterial arch). For NCE-MRA, image quality and arterial stenosis were evaluated independently by the two radiologists with the same analysis methods four weeks later. The sensitivity, specificity, positive predictive value, negative predictive value and accuracy of NCE-MRA (only refer to those arterial segments that were considered as diagnostic on CE-MRA) were calculated using CE-MRA as a reference standard. An intention-to-diagnose approach was used for calculating diagnostic accuracy and non-diagnostic segments on NCE-MRA were considered to have a stenosis [2]. Statistical analysis was performed to determine the difference of image quality between the two techniques and evaluate interobserver agreement for assessing significant arterial stenosis.

Results: All patients successfully underwent both NCE-MRA and CE-MRA studies. A total of 264 calf arterial segments and 352 pedal arterial segments were obtained in the 45 patients (Two patients had amputation in unilateral leg). The average number of diagnostic arterial segments and image quality by the two readers were detailed in **Table 1**. There was no significant difference in the number of diagnostic arterial segments between the two techniques in calf, but the image quality of CE-MRA was significant higher. In foot NCE-MRA significantly outperformed CE-MRA. The diagnostic accuracy of NCE-MRA for detecting significant stenosis (≥50%) was given in **Table 2**. Interobserver agreement between the two readers for diagnostic accuracy was excellent in calf (k=0.95) and good in foot (k=0.79). NCE-MRA also demonstrated excellent delineation (high contrast) for mild luminal narrowing and small collateral arteries both in calf and foot (**Figure 1**).

Table 1 Comparison for number of diagnostic arterial segments and image quality between CE-MRA and NCE-MRA in 45 patients with diabetes

	Number of diagnostic arterial segments		Image quality	
	Calf (n=264)	Foot (n=352)	Calf (n=264)	foot (n=352)
CE-MRA	260 (98%)	203 (58%)	3.5±0.7	2.0±1.0
NCE-MRA	258 (98%)	310 (88%)	3.3 ± 0.7	3.0 ± 0.9
P value	1.0	<0.001	<0.001	<0.001

Note: Data of NCE-MRA are average value by reader 1 and 2. P values were derived by using the Chi-square test for number of diagnostic arterial segments and Wilcoxon signed rank test for image quality.

Table 2 Diagnostic accuracy of NCE-MRA for detecting significant stenosis (≥50%) using CE-MRA as standard reference in 45 patients with diabetes

	Sensitivity	Specificity	PV＋	PV－	Accuracy
Calf (n=260)					
Reader 1	97 (59/61)	99 (197/199)	97 (59/61)	99 (197/199)	98 (256/260)
Reader 2	97 (59/61)	99 (198/199)	98 (59/60)	99 (198/200)	99 (257/260)
K value	0.95				
Foot (n=203)					
Reader 1	93 (30/33)	96 (164/170)	83 (30/36)	98 (164/167)	96 (194/203)
Reader 2	91 (29/33)	95 (162/170)	78 (29/37)	97 (162/166)	94 (191/203)
K value	0.79				

Note: Data are % (raw data). PV+: positive predictive value; PV-: negative predictive value. Spearman's kappa statistic was used to calculate k value.

Discussion: NCE-MRA using FSD-SSFP demonstrated a comparable percentage of diagnostic arterial segments and image quality with CE-MRA in calf, although the reduction in image quality was statistically significant, primarily due to the signal contamination from deep veins and soft tissues (**Figure 2**). However, the artifacts had little impact on the evaluation of the arterial lesions because the sufficient contrast between arteries and surrounding deep veins or soft tissues. NCE-MRA using FSD-SSFP had a high diagnostic accuracy for detecting significant arterial stenosis and excellent interobserver agreement. In addition, NCE-MRA showed a high performance in the visualization of foot arteries. It can be used as an alternative method for the detection of lower-extremity arterial disease in diabetic patients or those who can not receive contrast agent.

References: 1. Fan Z et al. MRM 2009; 62:1523. 2. Dewey M et al. Ann Intem Med 2006; 145:407.

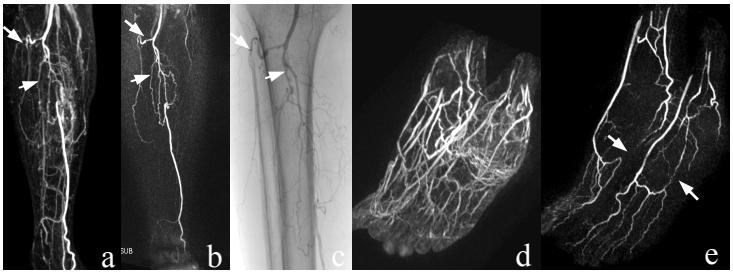

Fig.1: NCE-MRA demonstrated excellent delineation for severe arterial lesions (long arrow) and small collateral arteries (short arrow) in calf (a-CE-MRA, b-NCE-MRA, c-DSA, M/65) and in foot (d-CE-MRA, b-NCE-MRA, F/68).

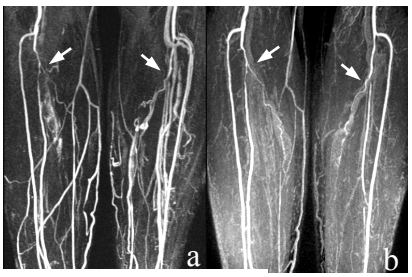

Fig.2: Artifacts of deep veins or soft tissues had little impact on the delineation of the arterial lesions on NCE-MRA (long arrow) in calf (a-CE-MRA, b-NCE-MRA, 59/M).