Non-gadolinium enhanced MRA of the distal lower extremities

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Purpose: Currently, contrast-enhanced MRA techniques are the most accurate and widely utilized method for non-invasive assessment of the lower extremities, and comparable to and potentially superior to DSA in imaging the calf[1]. A non-contrast technique has emerged that uses an ECG-triggered 3D Half Fourier acquisition single shot turbo spin echo (HASTE) sequence described initially by Miyazaki et al. in 1998[2-4]. In this study, non-contrast ECG-triggered HASTE (NC) is compared to two contrast-enhanced MRA techniques, time-resolved (TR) and bolus chase (BC) for assessment of the infragenual arteries.

Methods: NC and contrast-enhanced MRA runoff examinations were performed on 16 consecutive patients (M=13, F=3, mean=70 yr, range: 37-87 yr) referred for claudication (n=10), critical ischemia (n=3) and for suspected distal emboli (n=3). All examinations were performed at 1.5 T (Avanto and Symphony, Siemens Medical Solutions) with a multichannel peripheral phased array coil. Three techniques were employed for the assessment of the infragenual arteries from tibial plateau to metatarsal bases: non-gadolinium enhanced MRA (NC), time resolved gradient echo 3D MRA (TR) and bolus chase GE 3D MRA (BC). In all examinations, a single 500 mm FOV was used with identical coronal and anterior-posterior coverage, with slice thickness of 0.8-1.0 mm, and parallel imaging (GRAPPA) was utilized in all sequences (r=2).

Initially, NC images were acquired using an ECG-gated HASTE sequence with the following parameters: TR/TE =2xR-R interval/49, FA=130-180°, voxel size: 2.6 x 2.0 x 0.8mm, TA = 4 min (range 3-5 min). A nonselective inversion recovery pulse for fat and background signal suppression was used. In this technique, arterial flow voids are obtained in systole, with "bright blood" imaged in veins in systole, and in both arteries and veins in diastole. Subtraction of the systolic and diastolic images results in the depiction of arterial flow alone. An appropriate trigger delay for diastolic images was obtained for each patient with a "scout" 2D ECG-gated scan. 3D TR MRA was then performed using a 3D T1 FLASH sequence with the following parameters: TR/TE =2.46/0.92; FA=15°; voxel size: 2.2 x 1.3 x 0.8 mm; TA= 8-10s; centric reordering; zero interpolation, and view-sharing factor of 3 (TREAT, Siemens Medical Solutions). The TR sequence was performed 8 times following the injection of 10ml of Gd-DTPA (0.05 mmol/kg) at 2 ml/sec, with optimal time determined by a test bolus at the level of the distal aorta. Finally, 3 station moving table BC MRA was performed from the diaphragm to the feet using a 3D T1 FLASH sequence with parameters for the third station: TR/TE =3.3/1.2, FA=25°, voxel size: 2.2 x 1.3 x 0.8 mm, TA = 17-25 sec. Imaging was performed before and after the injection of 20ml of Gd-DTPA at 2ml/sec, followed immediately by 10ml at 1ml/sec and 20 cc saline at 1ml/sec, with timing determined from the original test bolus.

Data sets were randomized for retrospective review by two radiologists blinded to patient identity and pathology. Source data, subtracted and MIP images were assessed for technical quality, and clinical information. Factors that hindered interpretation were recorded. The visualized lengths of 10 segments per leg (bilateral distal popliteal arteries; tibioperoneal trunk; proximal and distal anterior tibial, posterior tibial and peroneal arteries; dorsalis pedis; and plantar arteries) were scored as follows: 1, ≥ 50% expected length of normal artery; 2, <50%; and 3=total occlusion. Stenoses were scored as follows: 0=no stenosis, 1=1-29%, 2=30-69%, 3=70-99%, and 4=occlusion. Confidence was scored on a 5 point ordinal scale. Any retrograde flow detected on the TR study was documented. The reference for evaluation was a consensus interpretation of all three sequences by both readers (CI). Correlation was made with ankle-brachial index, conventional digital subtraction angiography and ultrasound studies when available.

Results:

Of the 16 patients, 13 patients were included in the final cohort. Three patients were excluded because the NC exam was uninterpretable for both readers due to technical factors. Factors inhibiting diagnosis included off axis resolution, inaccurate trigger delay for diastolic images and motion for NC images (n=9), noise artifact for TR images, and severe venous contamination for BC images (n= 2). A total of 248 segments were examined, with 242 demonstrated on NC images, 247 on BC images and all 248 on TR images.

Table 1	BC	TR	NC
Length	215/247 (87%)	215/248 (87%)	188/242 (75%)
Stenosis	204/247 (83%)	204/248 (82%)	145/242 (60%)
% of segments that agree with reference assessment			

Based on a mixed model analysis of variance, there were significant differences among methods with respect to length ($p<0.0001$) and stenosis ($p=0.021$) and significant differences among non-standard methods with respect to absolute error in length ($p<0.0001$) and absolute error in stenosis ($p<0.0001$). When multiple pairwise comparisons were made, adjusted with Tukey's HSD procedure, significantly less vessel length was imaged on NC images. No significant difference between TR, BC, and CI lengths was found. With regards to degree of stenosis, a significant difference was calculated between BC and NC images ($p=0.021$), but not identified between NC and CI, NC and TR, TR and BC, BC and CI or TR and CI. BC showed the closest correlation with the reference standard (CI) with the lowest absolute errors for length and stenosis. NC had a significantly different larger mean absolute error in length and stenosis compared with the BC and TR techniques ($p<0.05$).

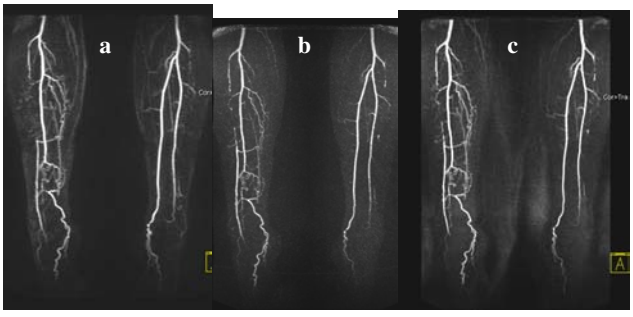

Figure 2 a) NC; b) TR; c) BC MIP subtraction images demonstrating excellent image quality and spatial resolution, and bilateral ATA, R peroneal segmental occlusions

Conclusion: In our early experience, non-gadolinium enhanced MRA of the lower extremities represents a potential alternative or complement (where such difficulties as inaccurate timing or severe venous contamination arise) to contrast-enhanced techniques. At present, undervisualization of the infragenual vessels is apparent. However, with continued refinement, it may provide a valuable entirely non-invasive assessment of the vascular system in the future.

References:

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