Non contrast enhanced MRA of the lower extremities using an ECG-gated variable flip angle 3D fast spin echo sequence

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Purpose: Contrast-enhanced MRA is routinely used for peripheral MRA and is comparable to and potentially superior than digital subtraction angiography (DSA) in the calf[1,2]. However, with the association of gadolinium chelates and Nephrogenic Systemic Fibrosis in patients with severe renal disease[3], a viable non-contrast MRA technique is desirable. A non-contrast ECG-triggered 3D half Fourier acquisition single shot turbo spin echo (HASTE) sequence[4] described initially by Miyazaki et al [5] can lead to vessel blurring due to long echo train lengths and tendency to overestimate disease, partly related to suboptimal trigger delays. We use an ECG gated turbo spin echo SPACE (Sampling Perfection with Application optimized Contrasts using different flip angle Evolutions)[6,7] sequence to image from the common femoral artery to midfoot. Shorter interecho spacing and a shorter acquisition window improve spatial resolution and timing of systolic and diastolic acquisitions.

Methods: Peripheral MRA runoff examinations were performed on 11 consecutive patients (M=8,, mean=69 yr) referred for claudication (n=7), critical ischemia (n=2), atheroembolic disease (n=1) and lower extremity edema (n=1). Average heart rate was 68 bpm (range 53-95), with 1 patient in atrial fibrillation at 91 bpm. All exams at 1.5 T (Avanto, Siemens) used a multichannel peripheral phased array coil. Initially, non-contrast enhanced images (NC) were acquired over 2 stations: TR/TE = 2 R-R intervals/17 ms, variable flip angle, voxel size: 1.5 x 1.1 x 1.5 mm, TA = 2 min 30 seconds per station, FOV 440mm. With this technique, arterial flow voids are obtained in systole. Bright signal is seen in veins in systole, and in both arteries and veins in diastole. Systolic and diastolic image subtraction results in an arteriogram. Two echo trains were used per slice, with 45 echoes per heartbeat, interecho spacing of 2.4ms (echo train duration 110 ms). Flow spoiling gradients of 25% of half readout gradient area accentuated differences between arterial and venous flow. Systolic and diastolic trigger delays were based on a 2D phase contrast "scouts". Time-resolved MRA (TR) of the calf station was then performed with 10 acquisitions of a 3D FLASH sequence: TR/TE =2.67/1.08; FA=25°; voxel size: 1.2 x 1.1 x 1.2 mm^3; effective temporal resolution 6.4s; view sharing (TWIST, Siemens) with 7.5ml of Gd-DTPA at 2 ml/sec. Finally, three-station moving table bolus chase MRA (BC) was performed using a 3D FLASH sequence: TR/TE =2.94/0.95, FA=25°, voxel size: 1.6 x 1.0 x 1.3-1.4 mm^3, TA = 11-13 sec, and 22.5 ml Gd-DTPA Imaging FOV was 500 mm for both contrast techniques. Parallel imaging with an acceleration factor of 3 was used for all sequences.
Contrast and NC MRA data sets were randomized for retrospective review by two radiologists using source data, subtracted and MIP images. Studies were assessed for diagnostic quality. The most severe stenosis within each of 19 segments per leg was graded: 0=no stenosis, 1= <50%, 2=≥50%, 3=occlusion. The length of greatest segmental stenosis was graded: 0=none, 1= ≤1cm, 2= >1cm, 3=entire segment. Reference standard was a consensus interpretation of both contrast enhanced sequences.

Results: 393 segments, as assessed by the reference standard, demonstrated hemodynamically significant stenoses (≥50%) in 98 (24.9%) segments. 2 independent readers assessed all segments using the non contrast technique (786 segments in composite). 737 (93.8%) segments were considered diagnostic. Sensitivity, specificity, overall accuracy, positive predictive value (PPV) and negative predictive value (NPV) of the non contrast sequence for hemodynamically significant stenosis (including non diagnostic segments) compared with the reference standard was 84.2%, 83.4%, 83.6%, 74.3% and 95.5%, with significant differences compared with contrast enhanced MRA (93.4%, 90.0%, 96.8%, 93.9% and 97.8% respectively), p<0.001, with the exception of negative predictive value (no significant difference). For length assessment, absolute error was greater for the non contrast compared with the contrast enhanced sequence (0.32± 0.60, compared with 0.13 ± 0.35, p < 0.001). Factors limiting NC interpretation included loss of signal at the cranial and caudal ends of the imaging slab secondary to B1 inhomogeneity (n=36 segments), motion (n=18), metallic artifact from orthopedic hardware (n=5) and suboptimal subtraction of venous signal in proximal thigh segments (n=20).

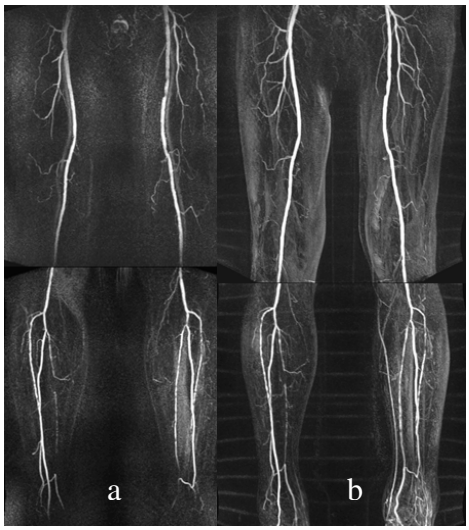

Figure 1. a) NC and b) BC MIP subtraction images demonstrating mild to moderate left superficial femoral artery stenoses and multifocal high grade stenoses/ occlusions of the right posterior tibial artery and disease of left anterior and posterior tibial arteries. Note signal loss caudally affecting the pedal vessels on NC images, a B1 inhomogeneity effect.

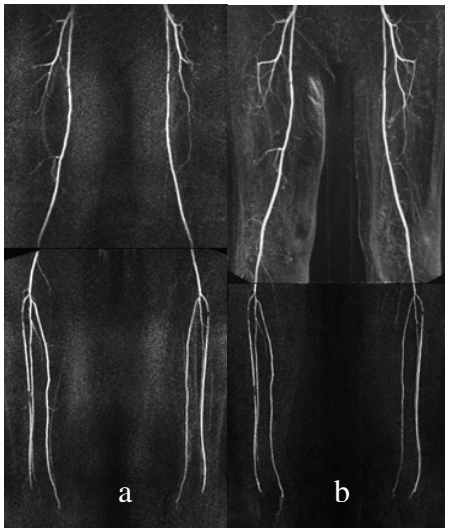

Figure 2. a) NC and b) BC (thigh) and TR (calf) MIP subtraction images demonstrating focal bilateral superficial femoral artery and anterior tibial artery stenoses. The BC calf station was affected by venous contamination.

Conclusion: Non-gadolinium enhanced MRA of the lower extremities using an ECG-gated fast spin echo technique with variable flip angle is feasible with high negative predictive value. It allows for a shorter acquisition window than a previously described ECG-gated HASTE MRA[5], potentially reducing vessel blurring that occurs with long echo train lengths, and allowing for high spatial resolution imaging with short interecho spacing and shorter acquisition times, with less susceptibility to tachyarrhythmias. Further optimization includes addressing B1 inhomogeneity by greater overlap of imaging fields of view.

References

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