Dedicated Calf MRA at 3T: Comparison of time-resolved MR Angiography with interleaved stochastic trajectories (TWIST) with standard high-resolution 3D contrast enhance MR Angiography (HR ceMRA)

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Introduction: Conventional high-resolution contrast enhanced MRA (HR ceMRA) has been shown to be excellent imaging technique for the diagnosis of peripheral arterial disease. A current limitation of this technique is venous contamination in the calf station. Time-resolved contrast-enhanced 3D MR angiography (tr-ceMRA) allows for discrimination between arterial and venous enhancement by rapidly acquiring consecutive 3D ceMRA with spatial resolution lower than HR ceMRA. Time-resolved imaging with interleaved stochastic trajectories (TWIST) is a view sharing technique that undersamples the periphery of k space to increase temporal resolution as compared to traditional tr-ceMRA (1-3). The purpose of this study is to evaluate the diagnostic performance of TWIST as compared to HR ceMRA in the distal lower extremity.

Methods: Both TWIST and HR ceMRA were performed in 8 patients (6 males, 2 females; mean age 49.4 years; range 18-70 years) referred for evaluation of clinically suspected arterial disease of the lower extremity. All exams were performed on a 3T whole body MR system (Trio, Siemens Medical Solutions, Malvern, PA) using a dedicated peripheral vascular phased array coil. TWIST imaging acquired 44 consecutive 3D datasets of the calf station in just over 1.5 min using the following parameters: TR 2.86 ms, TE 1.18ms, 512 x 420 matrix, central k-space sampling size 18%, peripheral sampling density 20%, parallel imaging (GRAPPA) acceleration factor 2, which yielded a voxel size of 1.0 x 1.0 x 4.0 mm and a temporal resolution of 2.2 sec. 4 secs before initiation of TWIST, 10ml of gadobenate dimeglumine (Multihance, Bracco Imaging, Milan, Italy) was injected at 2 ml/sec. After TWIST, a 3 station (abdomen/pelvis, thigh, calf) HR ceMRA was acquired in the arterial phase, as determined by timing bolus, with the following parameters for the calf station: TR 2.88 ms, TE 1.2 ms, 512 x 360 matrix, GRAPPA acceleration factor 3, which yielded a voxel size of 1.0 x 1.0 x 0.9 mm and a scan time 26 sec. 10 ml of Multihance was injected at 1.6 ml/sec followed by 10 ml at 0.6 ml/sec for the HR ceMRA. Two experienced vascular radiologists reviewed arterial segments of the calf station for both TWIST and HR ceMRA independently, in a blinded fashion, and randomly on separate occasions to reduce bias. A consensus reading using both TWIST and HR ceMRA served as the reference standard. The following 11 arterial segments per lower limb were analyzed: popliteal artery, tibio-peroneal trunk, and proximal, middle, and distal thirds of the anterior tibial, posterior tibial, and peroneal arteries. Presence or absence of stenosis was assessed on a graded scale (1= <50% stenosis, 2= ≥50% stenosis, 3= Occluded). Confidence was assessed on a four point Likert scale for all segments per limb (1. Ability to grade stenosis and detect occlusion is high. 2. Limited ability to grade stenosis, occlusions easily identifiable. 3. Unable to quantify stenosis. Limited confidence in identifying occlusion. 4. Non diagnostic). Contrast-to-noise ratios (CNR) were performed for all limbs at four levels: the popliteal artery and tibio-peroneal trunk (POP), proximal (PROX), middle (MID) and distal (DISTAL) third of the runoff arteries using the greatest signal available at each level (CNR = [SIvessel – SIadjacent soft tissue]/noise; SI=signal intensity, noise=standard deviation of SI outside the body). Sensitivity and specificity were calculated overall and at each level for TWIST and HR ceMRA, considering a stenosis greater than 50% or occlusion as positive. 95% confidence intervals (CI) were calculated for sensitivity and specificity using the Wilson score interval. Paired t-test was employed to detect significant differences between HR ceMRA and TWIST for CNR and confidence score. Means are reported +/- standard deviation.

Results: There were 16 limbs with 176 arterial segments available for comparison. 11 of the 25 diseased segments were at the DISTAL level. Overall CNR was 104 +/- 28 and 201 +/- 91 for TWIST and HR ceMRA, respectively (p=0.008). For TWIST, CNR was significantly decreased in the MID and DISTAL levels as compared to the PROX level; whereas with HR ceMRA, CNR was not significantly different among runoff levels (Figure 1). Overall sensitivity for TWIST was 0.86 (CI [0.74 – 0.93]) and for HR ceMRA was 0.82 (CI [0.69 – 0.90]). Overall specificity for TWIST was 0.87 (CI [0.82 – 0.90]) and for HR ceMRA was 0.96 (CI [0.93 – 0.97]). There were no differences between TWIST and HR ceMRA in respect to sensitivity by level. There was also no significant difference between TWIST and HR ceMRA at the PROX and MID levels in respect to specificity. However, TWIST demonstrated a significantly lower specificity at the DISTAL level as compared to HR ceMRA (Figure 2), where it accounted for 26 false positives as compared to 4 false positives for HR ceMRA. The overall confidence score was 1.2 +/- 0.5 for TWIST and 1.2 +/- 0.5 for HR ceMRA. There was decreased confidence in diagnosis with progression to more distal levels, but no significant difference was noted between TWIST and HR ceMRA at any level (p>0.05)

Discussion: In our study, TWIST performed well at the calf station when compared to standard HR ceMRA. A major limitation for TWIST is overestimation of the degree of stenosis at the most distal level of the runoff arteries, as evidenced by a significantly higher number of false positives and lower specificity. This finding was often noted as a focal high grade stenosis on the TWIST images, with a normal appearing vessel on the HR ceMRA (Figure 3). This limitation is likely attributable to decreased overall CNR in comparison to the HR ceMRA technique. In the larger proximal vessels, this is inconsequential, but becomes import as the vessels tapper distally. CNR limitation is compounded by significant decrease in CNR at the distal level as compared to the proximal level; a characteristic that is not shared by HR ceMRA. Most concerning is there was no significant difference in confidence scores between TWIST and HR ceMRA at the DISTAL level.

Conclusion: At 3T, TWIST and HR ceMRA perform similarly, thus a combined MR imaging protocol including both TWIST and HR ceMRA provides a robust approach to the assessment of calf arteries that would not be limited by venous contamination. However, TWIST is limited by overestimation at the most distal level of the calf station and this must be considered when planning treatment for patients with distal peripheral artery disease.

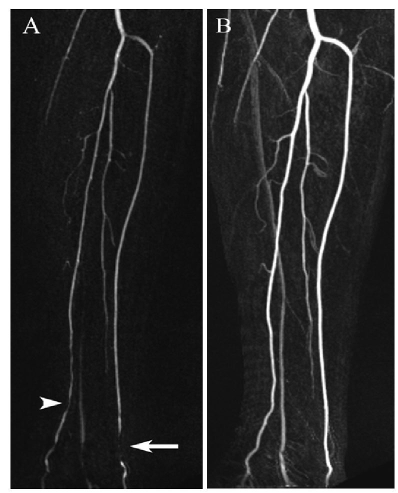

Figure 3: Calf station of left lower limb in patient with normal runoff arteries. (A) TWIST demonstrates focal occlusion of the distal anterior tibial artery (arrow) and a high grade stenosis of the distal posterior tibial artery (arrowhead) (B) HR ceMRA demonstrating normally appearing runoff arteries.

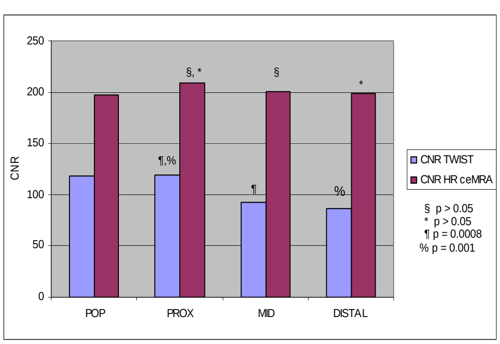

Figure 1. Segmental arterial CNR with t-test values

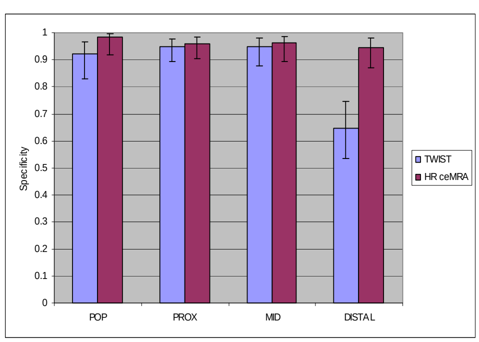

Figure 2. Segmental specificity with 95% CI bars

References:
1.Ersoy H, et al. AJR 2008;190:1675-1684.
2.Schoenberg SO, et al. J Magn Reson Imaging 1999;10:339e64.
3.Vogt FM, et al. ISMRM; 2007. Berlin, Germany: May 19-25, 2007.