Comprehensive Magnetic Resonance evaluation of vascular malformations at 3T: comparison of Time-resolved Angiography With Interleaved Stochastic Trajectories (TWIST) with standard 3D contrast enhanced MR Angiography (ceMRA)

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Introduction Vascular lesions are divided according to Mulliken and Glowacki into two categories: hemangiomas and vascular malformations, the latter is classified into malformations of capillaries, veins, arteries, lymphatics, or combinations of vessels. MRI has an important role in categorizing these lesions and determining their extent. Recognizing whether the lesion is a low-flow or high-flow vascular malformation is very important when planning treatment decisions. The temporal resolution of contrast enhanced MRA even at 3T is still insufficient to assess flow dynamics, which is a requisite particularly for the comprehensive assessment of high-flow malformations of the arterio-venous and capillary-venous type. Recently, very fast time-resolved MRA techniques with high spatial resolution were introduced. It is the purpose of this study is Time resolved contrast enhanced MRA With Stochastic Trajectories (TWIST MRA) sequence on a 3 Tesla system and compare it to a standard 3D ceMRA technique. To the best of our knowledge, there is no published study which compares these MRI techniques at 3T in such a patient population. (1-3)

Materials and Methods Clinical and MR angiographic findings were reviewed for 4 female and 1 male patients resulting in 6 TWIST studies (one patient had two TWIST studies). Patients age ranged from 26 to 48 years (mean 36.6 years). All imaging studies were performed on a 3T scanner (Trio, Siemens Medical Solutions, Malvern, PA) using either a 6 channel body matrix RF coil in combination with a built in spine coil or a dedicated peripheral vascular array coil. Catheter angiography / venography was available for 3 patients. Our MRI protocol for the examination of patients with peripheral vascular malformations includes T1w TSE and STIR sequences as well as a ceMRA sequence followed by post-contrast T1wTSE with and without fat suppression. To this protocol we added TWIST MRA, which was performed before the ceMRA. TWIST imaging acquired 44 consecutive 3D in just over 1.5 min using the following parameters: TR 2.86 ms, TE 1.18 ms, flip angle 25 deg, FOV 500 mm, receiver bandwidth 650 Hz/Px, parallel imaging (GRAPPA) acceleration factor 2, which yielded a special resolution of 1.0 x 1.0 x 4.0 mm and temporal resolution of 2.2 sec per data set. Four seconds after the initiation of TWIST, 10 ml of gadobenate dimeglumine (Multihance; Bracco Imaging, Milan, Italy) were injected at a flow rate of 2 ml/sec. Subsequently, our standard 3D ceMRA sequence with subtraction imaging was performed with the following parameters: TR 3.85 ms, TE 1.07 ms, flip angle 40 deg, FOV 500mm, GRAPPA, acceleration factor 3, receiver bandwidth 740 Hz/Px yielding a spatial resolution of 1.5 x1.0 x 1.3 mm. 20 ml of Multihance was injected at 2 ml/sec for the standard ceMRA. Overall image quality, contrast bolus timing and the presence of artifacts were assessed qualitatively on a four point Likert scale (Image Quality: 1 = excellent, 2 = good, minor impairments but fully sufficient for treatment plan, 3 = poor, some impairment of image quality, but still diagnostic, 4 = non-diagnostic; Bolus Timing: 1 = excellent, 2 = good, minimal venous contamination, 3 = fair, allowing identification of all major vascular structures but not side branches, 4 = poor arterial enhancement; Presence of artifacts: 1 = absent, 2 = Mild, not affecting image interpretation, 3 = moderate, affecting image interpretation, 4 = severe, rendering study nondiagnostic). Contrast to noise ratio (CNR) was calculated for the inflow artery and outflow vein during greatest enhancement, as well as the vascular lesion during peak conspicuity when applicable ($CNR = [SI_{vessel} - SI_{adjacent\ soft\ tissue}]/noise$; SI=signal intensity, noise=standard deviation of SI outside the body). For each malformation, reviewers judged which sequence contributed more to the final radiologic diagnosis on a five point scale (Diagnostic contribution: 1=noncontributory to final diagnosis, 5=only sequence needed to make diagnosis).

Results The final clinical diagnoses in the six examinations were low flow venous malformation (n=3), capillary venous malformation (n=1), and high flow arteriovenous malformation (n=2). CNR for the inflow artery was 181 +/- 54 and 253 +/- 159 for TWIST and ceMRA, respectively; for the outflow vein it was 111+/-69 and 113+/-35 for TWIST and ceMRA, respectively; and for the vascular lesion was 64+/- 48 and 75+/-25 for TWIST and ceMRA, respectively. For TWIST, the image quality was excellent in 5 studies and good (minor impairment but fully sufficient for diagnostic planning) in one case of venous malformation. Mild artifact from the bowel was present in one case, not affecting interpretation. Bolus timing was excellent in all studies. For 3D ceMRA, image quality was excellent in all studies and no artifacts were appreciated. Bolus timing was excellent in 3 studies, with minimal venous contamination in one case and moderate contamination in two cases (capillary venous and venous malformations). Diagnostic contribution for TWIST was 5 in 1 studies (capillary venous malformation), 4 in four studies and 3 in one study. Diagnostic contribution for ceMRA was 4 in three studies, 3 in one study, and 2 in two studies.

Discussion Compared to our routine vascular malformation protocol using a standard ceMRA at 3T, the introduction of the TWIST sequence increased our temporal resolution and thus the ability to study flow patterns related to the vascular malformation. This resulted in significantly improved ability to diagnose especially capillary venous malformations (Fig.). However, the reliable separation between arterial and venous structures was still not feasible for arteriovenous malformations. This separation is necessary for treatment planning and thus remains the domain of catheter-based digital subtraction angiography which delivers acquisition rates up to 15 frames per second.

Conclusions A comprehensive MR imaging protocol for peripheral vascular malformations at 3T can benefit greatly from the addition of TWIST MRA. While CNR is inferior to ceMRA, the perfect bolus timing, absence of venous contamination, as well as the high temporal resolution allow confident diagnosis of capillary venous malformations, which is not possible on ceMRA due to venous contamination. For venous and arteriovenous AVM's the diagnostic contribution does not differ significantly between ceMRa and TWIST. In our center TWIST MRA is currently the MRA technique of choice for the MR angiographic evaluation of peripheral vascular malformations.

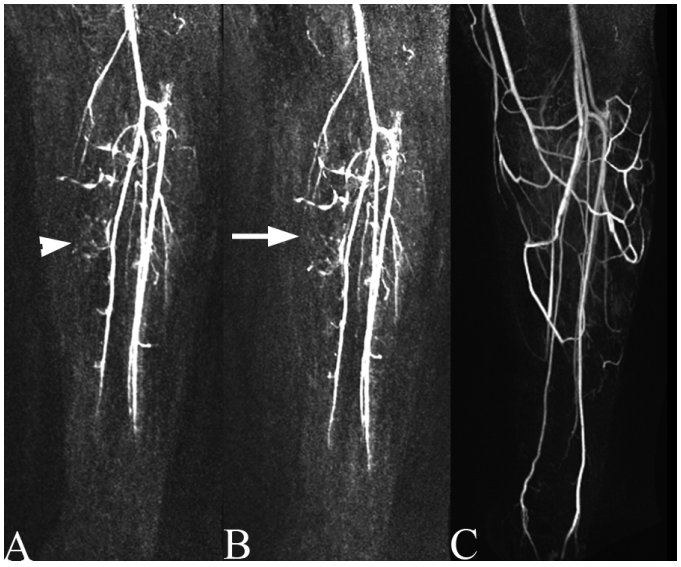

Figure. Left calf of 32 year old female patient with capillary venous malformation. **(A)** TWIST image in early arterial phase showing capillary lakes (arrow head). **(B)** TWIST image 2.2 sec after (A) showing development of tiny early draining veins (arrow). **(C)** Standard 3d ceMRA in the arterial phase demonstrating significant venous contamination without evidence of capillary shunting.

References

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