

Comprehensive Magnetic Resonance Imaging of the Hand and Forearm Vasculature at 3 Tesla using Time-resolved Angiography With Stochastic Trajectories (TWIST): Preliminary Clinical Results

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Introduction: Noninvasive imaging evaluation of the hand vasculature remains challenging, particularly in the distal arteries (1-4). Recent advances in magnetic resonance angiography (MRA), particularly the introduction of clinical 3 Tesla (T) MR scanners, has improved the ability to visualize small caliber target vessels (1-4). However, the temporal resolution of contrast enhanced MRA even at 3T is still insufficient to assess flow dynamics. The purpose of this study is to evaluate if the conspicuity of small vessels achieved with standard time resolved contrast enhanced MRA (tr-ceMRA) techniques can be maintained while significantly increasing acquisition speed using a comprehensive MR protocol that combines high resolution Time resolved contrast enhanced MRA With Stochastic Trajectories (TWIST MRA) with a high spatial resolution 3D volumetric fat suppressed interpolated T1-weighted sequence (3D VIBE) in a population with clinical evident disease of the hand vasculature. To the best of our knowledge, there is no published study which evaluates these MRI techniques at 3T in such a population.

Materials and Methods: Clinical and MR angiographic findings were reviewed for 8 examinations of 5 upper extremities. The patients' age ranged from 22 to 58 years (mean 36 years). All imaging studies were performed on a 3T scanner (Trio, Siemens Medical Solutions, Malvern, PA) using a 6 channel body matrix RF coil in combination with a built in spine coil. 5 upper extremities were evaluated with Syngo TWIST MRA and VIBE. High spatial resolution and temporal resolution TWIST MRA was acquired using a 3D sequence using parallel imaging (GRAPPA) with the following parameters: TR 3.1 ms, TE 1.35 ms, flip angle 25 deg, FOV 250 mm, receiver bandwidth 770 Hz/Px, GRAPPA acceleration factor 2, which yielded a spatial resolution of 0.7 x 0.7 x 1.0 mm and temporal resolution of 2.3 sec per data set. 20 ml of gadobenate dimeglumine (Multihance; Bracco Imaging, Milan, Italy) were injected at a flow rate of 2 ml/sec with initiation of TWIST MRA 4 sec after beginning injection. The acquisition time for one 3D dataset was 2.3 sec, and 45 consecutive datasets were obtained. Subsequently, high spatial resolution VIBE with parallel imaging was performed: TR 4.53 ms, TE 1.7 ms, flip angle 13 deg, FOV 230 mm, GRAPPA, acceleration factor 2, receiver bandwidth 510 Hz/Px yielding a spatial resolution of 0.5 x 0.5 x 0.5 mm. Image analysis of the arterial segments was performed by two observers in consensus. The following arterial segments were analyzed: arteries proximal to the wrist (ulnar and radial), palmar arch, common digital, proximal proper digital, mid proper digital, and distal proper digital. Segmental arterial conspicuity was assessed for both TWIST MRA and VIBE on a 4 point Likert scale (0= nondiagnostic, 1=poor data quality, diagnostic impairment, 2=suboptimal arterial signal, no diagnostic impairment, 3=good arterial signal). Segments were assessed for motion artifacts (0=absent, 1= present, but not effecting image interpretation, 2= present and affecting image interpretation, 3=severe). Contrast to noise ratio (CNR) was measured for each segmental level when possible ($CNR = [SI_{vessel} - SI_{adjacent\ soft\ tissue}] / noise$; SI=signal intensity, noise=standard deviation of SI outside the body). For each hand, reviewers considered the ability to come to a confident final radiologic diagnosis based on TWIST MRA alone and on VIBE alone. Arterial conspicuity scores are reported as mean \pm standard deviation (SD). Score differences within segments and between sequences were assessed with paired t-test.

Results: The final clinical diagnoses in the five examined extremities were vasculitis (n=2), Raynaud's syndrome (n=2), and disseminated Candida infection (n=1). All MR exams were of diagnostic quality. Arterial conspicuity scores on a segmental basis for both TWIST MRA and VIBE are as follows, respectively: proximal to wrist [2.9 ± 0.4 , 2.9 ± 0.4], palmar arch [2.8 ± 0.4 , 2.8 ± 0.4], common digital [2.4 ± 0.9 , 2.8 ± 0.4], proximal proper digital [1.6 ± 0.5 , 2.8 ± 0.4], mid proper digital [0.6 ± 0.5 , 2.8 ± 0.4], and distal proper digital [0.0 ± 0.0 , 2.8 ± 0.4] (Fig 1). In the proximal arteries (proximal to wrist, palmar arch, common digital), mean conspicuity score were not significantly different between TWIST MRA and VIBE. In the distal arteries (proximal through distal proper digital), mean conspicuity score was significantly greater for VIBE. Remarkably, there were no artifacts related to motion (mean rank = 0). Mean CNR measurements demonstrate progressively diminishing signal with more distal segments. The VIBE sequence produced greater CNR for all segments as compared to TWIST MRA technique (Fig 2). In 2 of 5 (40%) of TWIST MRA exams and 1 of 5 (20%) of VIBE exams, reviewers felt that the respective sequence alone was insufficient to arrive at a confident final radiologic diagnosis.

Discussion: Compared to our previous work using standard tr-ceMRA and VIBE at 3T, the introduction of the TWIST sequence increased our temporal resolution and thus the ability to study collateral flow patterns in the proximal circulation. Compared to the standard 3 T technique, the ability to assess both larger and medium sized target vessels was fully maintained. Like standard tr-ce MRA, TWIST MRA is very suitable for imaging of the proximal arterial segments, despite the inferior CNR. This is primarily due to the reliable separation between arterial and venous/enhancing structures which are closely related, particularly in the proximal hand. Additionally, TWIST MRA provides dynamic flow information. However, due to the superior CNR of VIBE and the larger anatomic separation of arterial and venous structures in the fingers, VIBE excels at imaging the small distal target vessels. Accurate evaluation of these small vessels is essential for the diagnosis of vasculitides and Raynaud's syndrome (Fig 3). VIBE also provides additional information in regards to soft tissue pathologies which are not easily discernable on TWIST MRA such as tenosynovitis and abscess collections. The inability to arrive at a confident diagnosis in a percentage of cases based on one sequence alone makes the use of a combined imaging protocol mandatory.

Conclusions: A comprehensive MR imaging protocol of the hand at 3T employing complementary techniques of TWIST MRA and VIBE allows for assessment of both proximal and distal vessels.

References:
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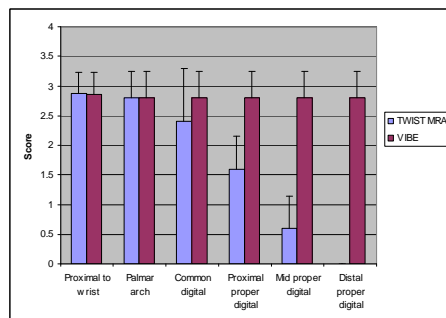


Fig 1. Arterial conspicuity score with SD bars

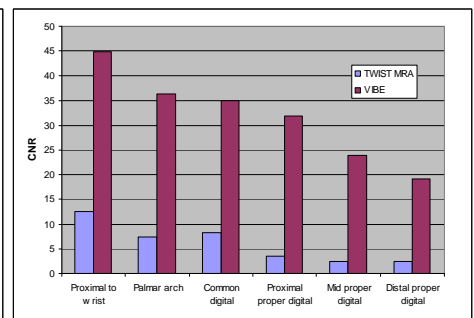


Fig 2. Segmental arterial CNR

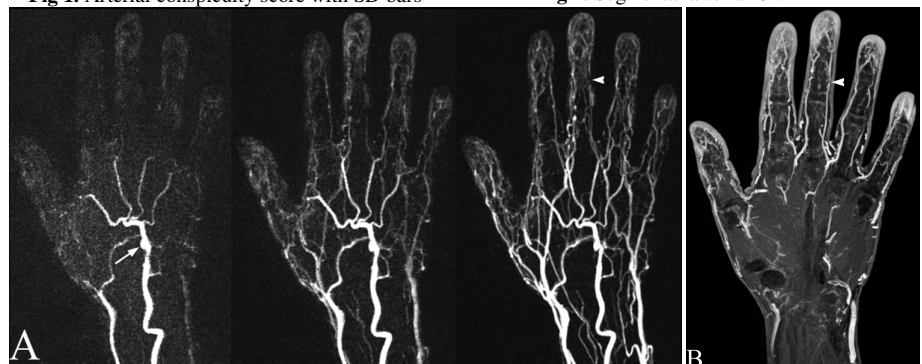


Fig 3. Patient with vasculitis. (A) Select serial TWIST images easily show a pseudoaneurysm centrally (arrow). Proper digital artery lesion is difficult to resolve (arrowhead). (B) Distal arteries are better visualized with VIBE, allowing for confirmation of a stenosis in the proper digital artery (arrowhead).