Initial evaluation of non-contrast-enhanced MRA in patients with peripheral arterial occlusive disease at 7 T

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Target audience: Clinicians and scientists interested in clinical application of body MRI at ultra-high magnetic fields

Purpose: Over the last two decades, MR angiography (MRA) with administration of gadolinium-based contrast media has evolved to become an excellent diagnostic tool for the non-invasive diagnosis of peripheral arterial occlusive disease (PAOD) in clinical routine. Nevertheless, with the recognition of Nephrogenic Systemic Fibrosis, which is associated with renal failure, the interest in non-contrast-enhanced (ne) MRA techniques has strongly emerged, as there is a high prevalence of chronic renal impairment with concomitant necessity for dialysis in patients with PAOD due to the association of PAOD with diabetes. The feasibility of ne-MRA of the lower extremity arteries at 7 T utilizing T1-weighted (w) Fast Low Angle Shot (FLASH) imaging was demonstrated recently in healthy volunteers [1]. The purpose of the current study was to achieve an initial experience with ne-MRA at 7 T in patients with PAOD.

Figure 1: Examinations were performed with a manually positionable AngioSURF table. The custom-built 16-ch coil was positioned around the table with 5 elements below and 11 elements above the

Methods: 7 patients with PAOD were examined on a 7 T whole-body MR system (Magnetom 7 T, Siemens Healthcare, Germany). A custom-built 16-channel transmit/receive coil [2] and a manually positionable Angio*SURF* table were utilized for multi-station imaging (Fig. 1). For ne-MRA, an axial T1w Turbo-FLASH sequence (TR 700 ms, TR 3.84 ms, FA 80°, BW 930 Hz/pixel, voxel volume 1 x 1 x 2 mm³, matrix 384 x 288) with phonocardiogram (PCG) gating was acquired at 7 T. TIAMO (Time-Interleaved Acquisition of MOdes, [3]) was integrated to obtain near homogeneous excitation uniformity with the alternating use of the CP^+ and CP^{2+} transmit modes as well as relative B_1 mapping for individual TIAMO shims. Acquisition time of an entire angiogram amounted to approximately 30 min, depending on the patient's heart frequency. All patients underwent a contrast-enhanced (ce) MRA at 1.5 T (Avanto, Siemens Healthcare, Germany) as standard of reference. Image analysis was performed by two radiologists in consensus in separate sessions while blinded to the other imaging technique. The degree of stenosis for each artery segment was defined (no stenosis/occlusion, low-grade stenosis < 50%, high-grade stenosis 50-99%, occlusion). The number of stenoses and occlusions was counted for each segment in both MRA techniques. High-grade stenosis and occlusion were specified as hemodynamically significant stenosis. Sensitivity and specificity of 7 T ne-MRA with regard to the number of segments with hemodynamically significant stenosis were calculated using the 1.5 T ce-MRA as the standard of reference.

Results: 7 T ne-MRA enabled a homogenous hyperintense arterial signal. Main and branch arterial delineation were excellent, and there was fairly uniform hypointense signal of background tissue. Arterial anatomy was accurately demonstrated both proximal and distal to stenotic disease. 154 artery segments were depicted with ce-MRA at 1.5 T. At 7 T only 124 segments were displayed and involved for analysis, as the iliacal region was displayed incompletely in four patients due to the fact that the fixed-diameter coil was too small to accommodate the lower abdomen and pelvis in these patients. Out of these 124 arterial segments included for analysis, 85 were characterized as being normal with 1.5 T ce-MRA. Of the remaining 39 arterial segments, 13 arterial segments were characterized as having one or more low-grade stenoses less than 50%, 16 segments were evaluated as having one or more high-grade stenoses equal to or greater than 50%, and 10 segments were deemed as being occluded. At 7 T ne-MRA, 85 arterial segments were characterized as being normal as well, whereas 11, 19, and 9 arterial segments were assessed as having low-grade stenosis less than 50%, high-grade stenosis equal to or greater than 50%, and occlusion, respectively. Regarding the total number of stenoses, 3 low-grade stenoses at 1.5 T were upgraded to high-grade stenoses at 7 T. Furthermore, one high-grade stenosis at 7 T that was located in the left tibiofibular trunk was categorized as an occlusion at 1.5 T. Out of the 124 included segments, 28 segments (23%) had hemodynamically significant stenosis evaluated with 7 T ne-MRA and 26 segments (21%) assessed with 1.5 T ce-MRA. The sensitivity and specificity values of 7 T ne-MRA for detecting segments with hemodynamically significant stenosis were 93% and 98%, respectively.

Figure 2: Angiogram of a 75-year-old female: ce-MRA at 1.5 T (A) and ne-MRA at 7 T (B) display a prolonged occlusion of the right superficial femoral artery (dashed arrows). Reperfusion of the popliteal artery is ensured due to several collateral and intramuscular branches of the profunda femoral artery, which were depicted in more detail at 7 T (B), possibly due to the higher spatial resolution. A further signal decrease in the proximal left superficial femoral artery was evaluated as high-grade stenosis in both imaging techniques (arrows).

Conclusion: Our results demonstrate high quality imaging of the lower extremity arteries with non-contrast-enhanced T1w MRA at 7 T in patients with PAOD. In this small group of patients, peripheral arterial stenosis and occlusion were identified and characterized accurately compared to ce-MRA at 1.5 T as standard of reference.

References:

[1] Fischer et al. Nonenhanced magnetic resonance angiography of the lower extremity vessels at 7 Tesla: initial experience. 2013. Invest Radiol. 48(7):525-34.
[2] Orzada et al. 16-channel Tx/Rx body coil for RF shimming with selected CP modes at 7T. ISMRM 2010.
[3] Orzada et al. RF excitation using time interleaved acquisition of modes (TIAMO) to address B1 inhomogeneity in high-field MRI. (2010). Magn Reson Med. 64(2):327-33.