Non-enhanced T1w imaging of the lower extremity arteries at 7 Tesla

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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 assessment of the lower extremity arteries. Nevertheless, with the recognition of Nephrogenic Systemic Fibrosis, which is associated with renal failure, the interest in non-contrast-enhanced MRA applications has re-emerged. First studies on non-enhanced MRA of the lower extremities at 1.5 T have demonstrated the feasibility and diagnostic potential of non-enhanced artery imaging [1, 2]. In parallel, an increase of the magnetic field strength has proven beneficial in terms of imaging at higher spatial resolution, enabling an improved delineation of vessel structures and pathologies. With the successful implementation of whole-body 7 Tesla MRI, the interest of this study was to investigate the feasibility of non-enhanced T1-weighted (w) MRA of the lower extremities.

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

Methods: Ten healthy volunteers were examined on a 7 T whole-body MR system (Magnetom 7T, Siemens Healthcare) in supine position. For image acquisition, a custom-built sixteen-channel transmit / receive coil [3] and a manually positionable Angio*SURF* table [4] for multi-station imaging were utilized (Fig. 1). The following T1w sequences were acquired non-enhanced in axial orientation: 2D FLASH without gating, Turbo-FLASH and QISS-FLASH with phonocardiogram (PCG) gating. TIAMO (Time-Interleaved Acquisition of MOdes, [5]) was integrated into the FLASH and Turbo-FLASH sequences to obtain near homogeneous image quality with the alternating use of the CP^+ and CP^{2+} transmit modes. Ten stations, each covering 12 cm, were acquired to visualize the vasculature from pelvis to feet. Qualitative image analysis was performed in the iliac, femoral, popliteal, and tibiofibular artery segments with regard to artery delineation and presence of artifacts using a five-point scale (5 = excellent vessel delineation to 1 = non-diagnostic). For quantitative image evaluation, the signal was measured in the specified segments and in the adjacent musculature of both legs to obtain contrast ratios ($CR = [S_{artery}-S_{muscle}]/[S_{artery}+S_{muscle}]$).

Results: All T1w sequences provided a hyperintense delineation of the arterial vasculature. Best image quality was found for the popliteal segment (FLASH 4.00, Turbo-FLASH 4.80, QISS-FLASH 4.50) (Fig. 2). Qualitative image evaluation demonstrated its superiority for the Turbo-FLASH in all artery segments (iliacal 3.10, femoral 3.95, popliteal 4.80, tibiofibular 4.47) (Fig. 3). FLASH without gating rated worse due to short, intermittent declines in vessel signal; this artifact could be successfully reduced with phonocardiogram gating in Turbo- and QISS-FLASH imaging. Quantitative analysis showed similar contrast ratios in all vessel segments, with highest values in the femoral (FLASH 0.63, Turbo-FLASH 0.68, QISS-FLASH 0.59) and popliteal segments (FLASH 0.68, Turbo-FLASH 0.74, QISS-FLASH 0.63). Acquisition time for all three sequences amounted to 98.2 min on average (2D FLASH 26.8 min, Turbo-FLASH 43.2 min, QISS-FLASH 28.2 min).

Figure 2: Maximum intensity projection of T1w non-enhanced sequences at 7 T in one subject providing a hyperintense delineation of the lower extremity arteries. TIAMO was essential to enable a homogeneous artery signal: QISS-FLASH without TIAMO suffered from B_1-field artifacts, resulting in signal loss particularly in the femoral and lower leg segments.

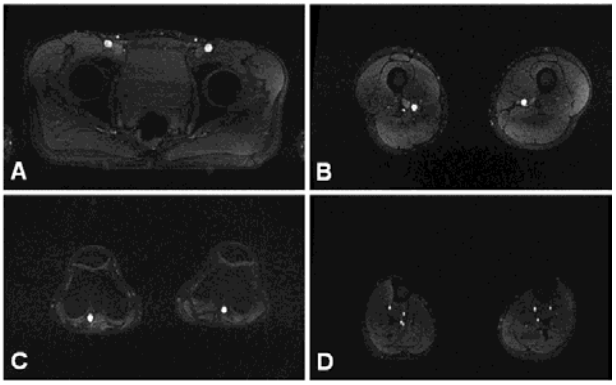

Figure 3: Axial source images of T1w PCG-gated Turbo-FLASH sequence in the iliac (A), femoral (B), popliteal (C), and tibiofibular (D) segments; this sequence was rated superior in the qualitative evaluation. Turbo-FLASH imaging enabled clearly definable vessels even in the lower leg segment with a high intraluminal signal.

Conclusion: Our results demonstrate high quality imaging of the lower extremity arteries with non-contrast-enhanced T1w MRA at 7 T in healthy subjects, with a superiority of PCG-gated Turbo-FLASH imaging. Comparison to contrast-enhanced and non-enhanced MRA at lower field strengths in patients will be the focus of future studies.

References:

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