In-Vivo Plaque Imaging of the Carotid Arteries at 7 Tesla: First Results

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Introduction: Atherosclerosis is a serious disease of the vessel wall causing high morbidity and disability worldwide. To identify high-risk plaque, accurate characterization and quantification of the plaque components in relation to the fibrous cap and the lumen is important [1]. Since the introduction of 3T MRI into clinical routine, advantages of the resulting high resolution have been shown in many applications and have improved vascular imaging as well [2,3]. Measurement protocols which have been optimized for MRI at field strengths of 1.5T or 3T cannot be directly transferred to 7T. Specific absorption rate (SAR) limitations, different relaxation times of the tissues, high-field related image artifacts, e.g. due to enhanced susceptibility effects, and the absence of dedicated coils require adjustments of the sequence parameters and measurement techniques in general. Our study aimed to optimize and evaluate sequences for plaque imaging at 7T.

Methods: This IRB approved study was performed in five healthy volunteers (three male, two female) and one patient (68-year-old female) with known irregularities of the vessel wall and a 50% stenosis of the right carotid artery diagnosed with 1.5T MRI. All measurements were performed on a Magnetom 7T whole-body scanner (Siemens Medical Solutions, Erlangen, Germany) with a 10-cm-diameter transmit/receive single loop coil (Rapid Biomed, Wurzburg, Germany) placed on one side of the subject's neck. The imaging protocol consisted of two gradient echo sequences (volume interpolated 3D FLASH (VIBE), magnetization-prepared rapid gradient echo (MPRAGE)) for high resolution non-contrast-enhanced MR angiography with a high vessel-to-background image contrast [4] for displaying the bifurcation and to reveal potential stenosis, plaque, or dissection of the vessel. Subsequently, pulse-triggered PD and T2 weighted turbo spin echo (TSE) sequences were optimized for detailed classification of the vessel wall and lumen.

Results: To take full advantage of the potentially higher signal-to-noise ratio at 7T, modifications of the sequences and parameters were necessary. A T1 weighted VIBE dataset with a resolution of 0.5x0.5x1.0 mm^3 and 80 slices could be obtained within 3:20 minutes without any SAR concerns (flip angle $\alpha = 10°$). For the MPRAGE, a combination of TR = 1800 ms, $\alpha = 4°$, and TI = 750 ms rendered best vessel-to-background image contrast with a resolution of 0.5x0.4x0.6 mm^3 and an acceptable TA = 7:57 minutes. For PD and T2 contrasts, echo times of 34 ms and 73 ms, respectively, in combination with fat suppression yielded best image quality with a resolution of 0.4x0.4x2.0 mm^3. However, SAR is a major issue for the TSE sequence, resulting in strong limitation of spatial coverage. A variable-rate selective excitation (VERSE) pulse [5] and a flip angle of 150° had to be selected. ECG triggering turned out to be difficult at 7T; peripheral pulse triggering provided a robust alternative.

Figure 1 shows images of the patient obtained at 7T (B-G) and one 1.5T image for comparison (A). The stenosis is clearly visible in the 7T images (B and C) and appears more severe in the 7T MIP than in the 1.5T MIP. Irregularities of the external carotid artery are shown in (D), and plaque is visible in both arteries in (E). The thickened vessel wall is shown in both PD and T2 weighted images of the common carotid artery in (F) and (G).

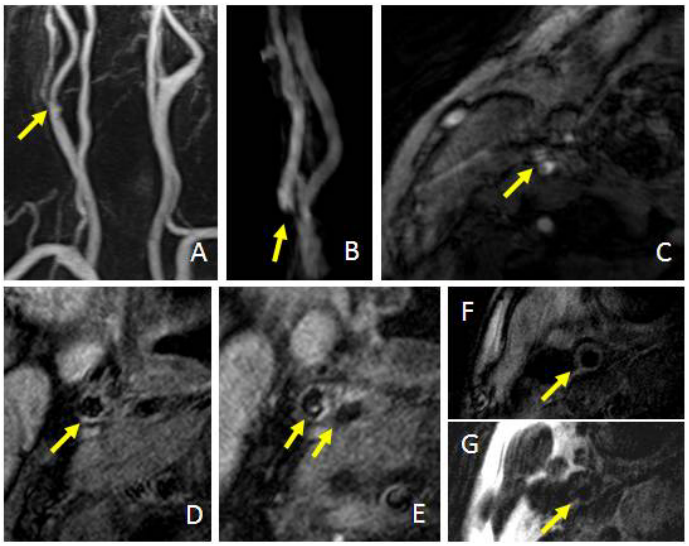

Figure 1: Images of the patient. First row shows a 1.5T MIP of a contrast-enhanced VIBE sequence (A) in comparison to (B) a 7T MIP and (C) axial source image of the non-contrast-enhanced 7T VIBE. In the second row 7T plaque images obtained with TSE are given: (D, E, F) PD-w and (G) T2-w. Arrows in (A-G) point to the stenosis in the right external carotid artery.

Discussion: This study demonstrates the feasibility and first experience in imaging plaque in the carotid arteries with a transmit/receive single-loop coil at 7T. SAR restrictions, difficulties with the ECG trigger, and high-field related image artifacts were identified as key challenges of 7T carotid MRI. Further studies are needed to investigate pathologies and to clearly distinguish between blood flow, susceptibility artifacts, and plaque. These initial results are part of an ongoing study investigating high-field carotid MRI in patients. A dedicated multi-channel carotid RF coil which allows for parallel imaging is currently under development.

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