Quantitative evaluation of the current status of carotid artery imaging at 7T with respect to 3T

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Introduction: MRI of the carotid arteries is important for risk assessment of atherosclerotic plaques, which can cause brain infarctions when they rupture. 3T MRI with a dedicated high end coil array is the current standard for carotid MRI. Increasing the field strength to 7T may increase the quality of risk assessment by utilizing the increased SNR for increased resolution and/or contrasts. However, apart from field strength, SNR depends on the used RF coil as well as the relaxation time constants T_1 and T_2. Since the RF field patterns of even equally sized RF coils will not match between the field-strengths, fair comparisons between 3T and 7T is challenging. Nonetheless, when the density in coil receivers is increased, optimized SNR [1] can be assured. In this current research, we quantified the SNR available in the carotids at 7T and 3T using high density receiver setups while assuring sufficient B_1^+ using a dielectric pillow (U-tube [2], 7T) or the body-coil (3T) as a transmitter. In addition, high resolution T2 maps were obtained to assess the T_2-relaxation differences in the vessel wall between the two field strengths, thereby enabling accurate performance measures..

Fig 1 7T receive array and its positioning

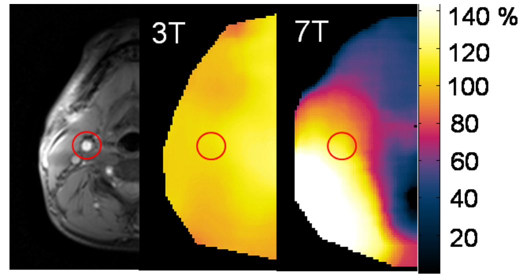

Fig 2 Actual flip angle maps at 3T and 7T (transverse plane of the neck). Optimized to 100% at the carotid artery (red circle)

Materials and methods: 5 healthy volunteers were scanned at 7T and 3T. At 7T, a separate transmit and receive array [2] was used. The receive array was a 30 channel small element bilateral array (15 elements per side). Figure 1 shows the receive elements and their placement schematically. The receive array at 3T had similar outer dimensions but consisted of only 4 element per side. **1)** Actual flip angle (AFI) maps were acquired and transmit power was calibrated for a given B_1^+ at the carotid arteries. **2)** High resolution multi-slice turbo spin echo (TSE) images were acquired with following scan parameters: acq. voxelsize = 0.4 x 0.4 x 1.5 mm^3, echo train length = 11 (incl 3 startups), refocusing angle = 80°, nr of slices = 15, T_R = 1000ms, $T_{E,\,k=0}$ = 33ms. **3)** T_2 maps were acquired from a multi echo TSE with 15 echo's and an echo spacing of 9ms, resolution 0.5 x 0.5 x 5.0 mm^3. **4)** SNR maps were calculated from a proton-density-weighted image (gradient echo, T_R/T_E = 200/2.1ms, flip angle = 6°) and corrected for the B_1^+ using the acquired AFI maps, assuming linear B_1^+ dependency in the low flip angle regime. Average SNR profiles as a function of depth were processed from this data. **5)** Finally, for the 7T receive array, the localized effect of coupling between the elements was estimated by acquiring two images: the first one was acquired separately per element while all other elements were detuned ("uncoupled"), the second one was acquired all together (coupled). From the ratio an estimated "couple-loss" map was reconstructed.

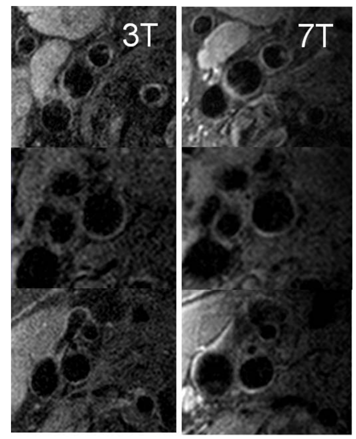

Fig 3 example high-res TSE images of three volunteers at 3T and 7T

Results and Discussion: Figure 2 shows the actual flip angle maps at both field strengths, indicating the importance of proper power calibration at 7T. Figure three shows qualitatively the improved vessel wall imaging at 7T. However, shorter T_2 at 7T (as shown in figure 4) causes extra restriction in echo train design. In figure 5, representative SNR maps are shown. Of these maps, the averaged SNR profile of all volunteers is show in figure 6. Incorporating the differences in transmit field, the huge SNR improvement below 20 mm depth is mainly due to the small receiver elements. Beyond 20 mm depth the SNR ratio 7T/3T is constant at 1.8 ± 0.2. This is lower than the expected theoretical 7/3 gain in SNR. Note though, that despite the low RF coupling between the high density receiver elements [2], still at distance, the combined effect causes 40% less SNR when compared to fully decoupled receivers (fig 7), paving way for potentially even more SNR in carotid MRI at 7T.

Conclusion: The current status in carotid artery imaging at 7T is that SNR improves compared to 3T despite the lower T2 values.

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References: [1] Hoult et al. J Magn Reson Imaging. 2000; 12(1):46-67, [2] Koning et al. MRM 2012, Jul 3.

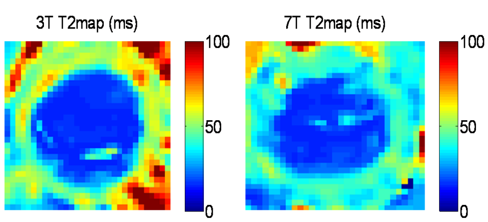

Fig 4 quantitative T_2 maps of the carotid vessel wall at 3T and 7T

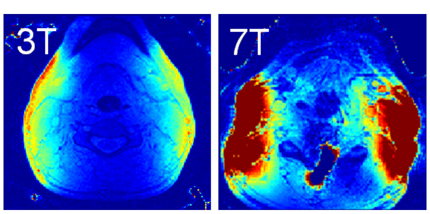

Fig 5 representative SNR map 3T versus 7T

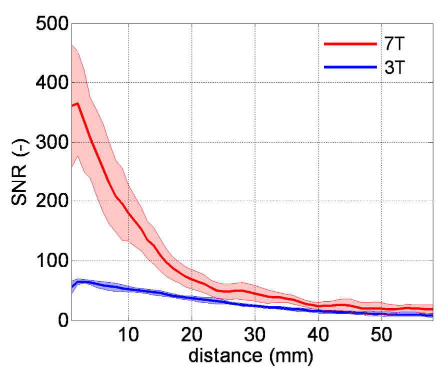

Fig 6 averaged SNR of all volunteers as a function of depth in the neck.

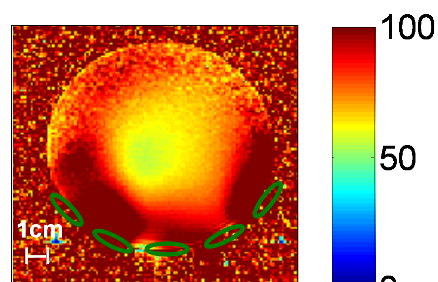

Fig 7 "couple loss" map of the used 7T setup, showing SNR loss compared to fully decoupled receivers (100% = no loss).