High Spatial Resolution MR Imaging of the Carotid Arteries at 7.0 T Using an 8 Channel Transceiver Coil Array

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Introduction: Todays clinical imaging of carotid artery stenosis is primarily performed with ultrasound and digital subtraction angiography. Magnetic resonance angiography and multi-contrast MRI allow for a comprehensive assessment of the degree of vessel stenosis and structural vessel wall alterations in order to evaluate stroke risk [1, 2]. Carotid MRI remains challenging due to anatomical constraints in the neck region, the need for blood suppression to avoid blow flow and pulsation induced artifacts and the versatile range of imaging contrasts required for a differential diagnosis between vulnerable and stable plaques. All these constraints translate into stringent technical requirements to balance signal to noise ratio, vessel wall-to-lumen contrast, immunity to blood flow, spatial resolution, and examination time. Recognizing these challenges together with the opportunities inherent to ultrahigh field MRI, it is conceptually appealing to pursue carotid imaging at 7.0 T. Admittedly, RF coil technology tailored for carotid imaging at 7.0 T is still in its infancy [3]. Therefore, this study proposes an 8 channel transmit/receive coil dedicated for MRI of the carotids. Its RF performance and RF safety are evaluated in electro-magnetic field simulations. The RF coils applicability for sub-millimeter spatial resolution carotid MRI is examined *in vivo* at 7.0 T.

Methods: The coil array comprises two sections to cover the left and right carotid. Each section contains 4 loop elements (Fig. 1A). The elements are organized in a 2 x 2 matrix. Both rows arranged in an interleaved fashion so that the element are shifted from each other by a half element size. For decoupling a capacitor has been placed on a common conductor. Other capacitors are equaly distributed around the loops to mitigate dielectric losses. The dimensions of the coil's loop elements are 60 x 60 mm. The overall dimension of the array is 110 x 160 mm. The layout uses 10 mm wide conductor, was etched on FR4 former with 18 µm thick copper and placed in acrylonitrile butadiene styrene casing produced by rapid prototyping (Fig. 1B). For each channel a cable trap was placed on the coaxial cable. The coaxial cable was terminated by a BNC connector. Electro-magnetic simulations were performed with CST MWS (CST AG, Darmstadt, Germany) to assure RF safety. Voxel model Duke from Virtual Family [4] was included into the simulation. The geometry and positioning of the coil were matched to reality using 3D images of the head/neck as a mask (Figure 1A). Specific-absorption-rate (SAR) was averaged over 10 g as suggested in EN 60601-2-33 Ed. 3. Studies in healthy volunteers (n = 5) were conducted using a 3D FLASH sequence (TE = 1.8 ms, TR = 7 ms, FA = 15) and FSE sequence (TE = 80 ms, TR = 14300 ms, FA = 144). No triggering method was used for image acquisition.

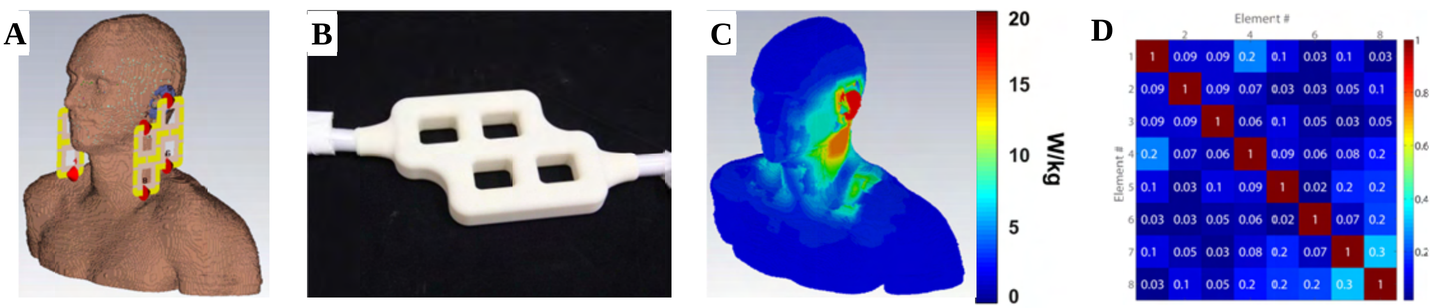

Fig. 1: A) Conductor layout of the 8 channel TX/RX RF coil, **B)** The coil with its casing **C)** SAR distribution, the eyes show low SAR values **D)** noise correlation matrix for all eight elements.

Results: Based on the simulations, the coil's RF power was limited to 8 W to stay within the 20 W/kg local SAR limit. The reflection characteristics of the elements were below -20 dB and the decoupling was better than -13 dB for neigboring elements. Loading the coil with different volunteers did not change the tuning (mean -18 dB) and decoupling (mean -17 dB) significantly. Mean unloaded Q was 96.41, mean loaded Q was found to be 23.13 resulting in a mean unloaded/loaded Q ratio of 4.16. All values of the noise correlation matrix were below 30 % (Fig. 1D). The proposed 8 channel Tx/Rx array provides depth penetration suitable for carotid imaging. Axial and sagittal views shown in Fig. 2 demonstrate the high image quality as well as the high level of contrast achieved for FSE and 3D FLASH imaging. The baseline SNR gain at 7.0 T together with the SNR provided by the carotid coil enabled an acquired spatial resolution of (0.4 x 0.4 x 1-2) mm^3 which is superior to the reported for traditional 3.0 T acquisitions using volume or dedicated phased array surface coils [5].

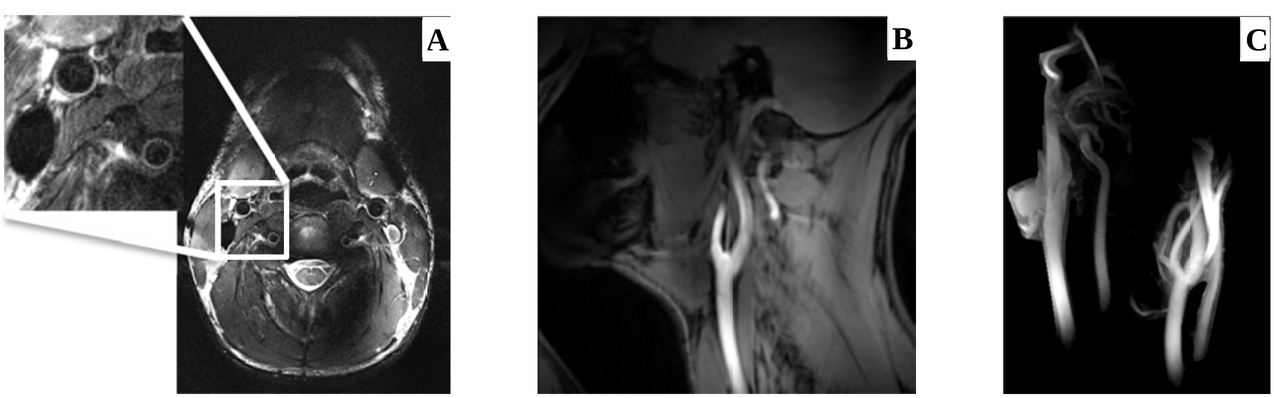

Fig. 2 - A) Transversal view of the carotid artery derived from FSE imaging (0.4 x 0.4 x 4 mm^3), **B)** Sagittal view of the carotid artery derived from 3D FLASH (0.5 x 0.5 x 1 mm^3) **C)** Maximum intensity projection reconstructed from 3D FLASH (0.4 x 0.4 x 1 mm^3)

Discussion: The proposed 8-element coil met the needs of isotropic, sub-millimeter in-plane spatial resolution imaging of the carotid artery. It provides patient comfort and ease of use due to its light weight. Structural images of high spatial resolution can be achieved, which show carotid wall morphology and vessel shape in great detail. A recognized limitation of this feasibility study is its assessment in a limited number of subjects. Therefore, efficacy of the proposed transceiver array in the clinical routine environment awaits further study. In a following study, the use of our transceiver array in patients with symptomatic and asymptomatic carotid plaques will be evaluated and compared to conventional 3.0 T imaging.

References: [1] D. P. Hinton, et al. (2006) Eur J Radiol [2] R. C. Cury, (2006) Invest Radiol. [3] O. Kraff, et. al. (2011) Invest Radiol. [4] A. Christ, et al. (2010) Phys Med Biol [5] D. P. Hinton-Yates, et al. (2007) Top Magn Reson Imaging