Design and Application of 5 Channel Tx/Rx Coil for High Spatial Resolution Laryngeal MRI at 7 Tesla

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Introduction: MRI holds great potential for monitoring of laryngeal tumor progression, for elucidating laryngeal and vocal fold anatomy together with the assessment of physiological processes associated with human phonation [1, 2]. Laryngeal MRI remains very challenging due to the subtle targeted structures, which translates into stringent technical requirements in balancing image contrast, spatial resolution and signal to noise ratio. Recognizing these challenges this study proposes a 5 channel transmit/receive coil dedicated for MRI of the larynx. Its RF performance is evaluated in electro-magnetic field simulations and its applicability for sub-millimeter spatial resolution laryngeal and vocal tract MRI is examined in volunteer studies at 7.0.

Methods: The coil array comprises 5 elements (Fig. 1A) that share a common conductor with decoupling capacitors. Other capacitors are equaly distributed around the loops to mitigate dielectric losses. The dimensions of the 5 coil elements were adapted to conform to an average neck. Element #1, #2, #4 and #5 have a loop size of (6 x 4) cm^2. The middle element #3 has a loop size of (6 x 5) cm^2 to improve the decoupling between elements #2 and #4.The layout with 12.5 mm broad conductors was etched on FR4 former and placed in ABS casing produced by rapid prototyping (Fig. 1B). The RF shield was positioned in the distance of 15 mm from the former. 5 cable traps were fixed behind the RF shield. EM simulations were performed (CST MWS, CST AG, Darmstadt, Germany) to assure RF safety. Voxel model Duke from Virtual Family [3] with 2 mm voxel resolution was included into the simulation. The geometry and positionig of the coil were matched to reality (Figure 1A). Other parameters of the simulations: 15 mil. mesh cells, accuracy -50 dB, frequency range 100-500 MHz, frequency of the monitors 297.2 MHz. The SAR was averaged over 10 g as suggested in EN 60601-2-33 Ed. 3. Based on this simulation the coils power was limited to 3 W to stay below the 20 W/kg local SAR limit. Volunteer studies (n = 6) were conducted using a T_1-weighted 3D gradient echo technique (TE = 2.8 ms, TR = 10 ms, FA = 9°, FOV = 12 x 12 cm^2).

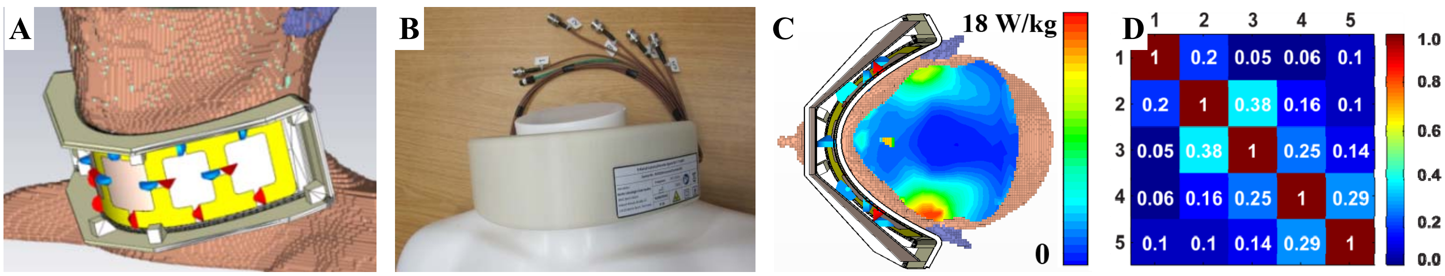

Fig. 1: A) Conductor layout of the 5 channel TX/RX RF coil, **B)** The coil placed on a mannequin. **C)** SAR distribution in a transverse slice **D)** noise correlation matrix for all five elements.

Results: The reflection characteristics of the elements were below -33 dB and the decoupling was better than -11 dB for neigboring elements and better than -15 dB for next neigbors. Loading the coil with volunteers with BMI's ranging from 20 to 25 did not change the tuning (mean -25.4 dB) and decoupling (mean -18.9 dB) significantly. Mean unloaded Q was 135, mean loaded Q was found to be 52 resulting in a mean unloaded/loaded Q ratio of 2.5. All values of the noise correlation matrix were below 40% (Fig. 1D). Basic B_{1+} shimming was performed by adjusting the cable length for each coil element. The proposed 5 channel TX/RX array provides depth penetration suitable for laryngeal imaging. Axial and coronal views shown in Fig. 2 demonstrate the image quality as well as the level of contrast achieved with 3D T_1-weighted imaging. The baseline SNR gain at 7.0 T together with the SNR provided by the larynx coil enabled an acquired spatial resolution of (i) (0.5 x 0.5 x 0.5) mm^3, (ii) (0.25 x 0.25 x 0.5) mm^3 and even (iii) (0.25 x 0.25 x 0.25) mm^3, which is superior to the spatial resolution of (0.5 x 0.5 x 1-2) mm^3 reported for traditional 3.0 T acquisitions using volume or dedicated phased array surface coils [2]. T_1-weighting facilitated discrimination between muscle soft tissue and non-ossified cartilage. Thyroid and cricoid cartilages are clearly visible (Fig. 2).

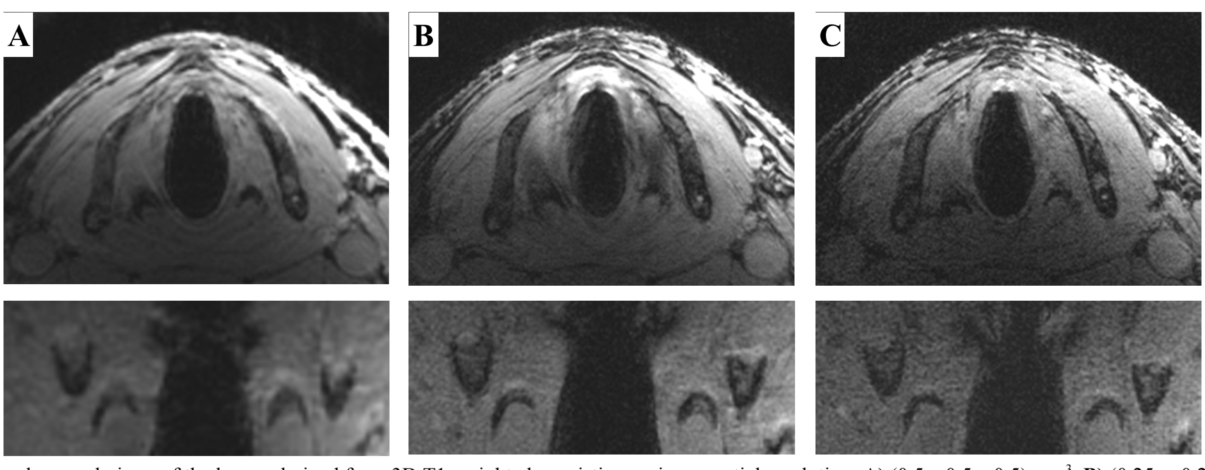

Fig. 2 - Axial and coronal views of the larynx derived from 3D T1-weighted acquistions using a spatial resolution: **A)** (0.5 x 0.5 x 0.5) mm^3, **B)** (0.25 x. 0.25 x 0.5) mm^3 and **C)** (0.25 x 0.25 x 0.25) mm^3

Discussion: The proposed 5-element coil exhibits an SNR advantage over previous two element TX/RX designs [4]. The 5-element laryngeal array was found to meet the needs of isotropic, sub-millimetre spatial resolution imaging of the larynx and the vocal tract at 7.0 T. It provides patient comfort and ease of use due to its light weight. We anticipate using this setup in further studies to gather reference data to be used in a finite-element model of phonation functions as well as in clinical research to study laryngeal tumour progression.

References: [1] Barral J. K. et. al., . Proc. Intl. Soc. Mag. Reson. Med. (2009), p. 1318., [2] Echternach M. et al. Proc. Intl. Soc. Mag. Reson. Med.(2009), p. 1323. [3] Christ A. et al. Physics in Medicine and Biology 2010; 55:N23-N38. [4] Frauenrath T. et al., Proc. Intl. Soc. Mag. Reson. Med. (2010), p. 894