High spatial resolution 3D MRI of the Larynx using a dedicated TX/RX phased array coil at 7.0T

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Introduction

MRI holds great potential for elucidating laryngeal and vocal fold anatomy together with the assessment of physiological processes associated in human phonation [1, 2]. However, MRI of human phonation remains very challenging due to the small size of the targeted structures, interfering signal from fat, air between the vocal folds and surrounding muscles and physiological motion. These anatomical/physiological constraints translate into stringent technical requirements in balancing, scan time, image contrast, immunity to physiological motion, temporal resolution and spatial resolution. Motivated by these challenges and limitations this study is aiming at translating the sensitivity gain at ultra-high magnetic fields for enhanced high spatial resolution 3D imaging of the larynx and vocal tract. To approach this goal a dedicated two channel TX/RX larynx coil is been proposed and its applicability for laryngeal and vocal fold imaging is examined in healthy volunteers.

Methods

A transceiver coil array (Figure 1) was constructed on a lightweight, flexible former, with two rectangular loops (butterfly) with a size of (10 x 8) cm² using low resistance copper tape. Capacitors were used to decouple both elements and to tune-up the coil. Both coil elements shared a common conductor. A capacitor was added to the shorter side of the coil elements so as to decouple nearest neighbors. Other capacitors were equally distributed to mitigate dielectric losses. The coil is power-supplied through two coax wires connected to the outer side of the loops for ergonomic reasons. Each wire includes a balloon to minimize interference of the wire inductivity with the coil elements. Each coil element was tuned to the Larmor frequency at 7.0 T (297.12 MHz) and the loops were detuned from each other at the same frequency by 16 dB. B1 shiming was done by adding a λ/4-line in one channel's RX-connection. Volunteers studies were conducted using a T_1-weighted 3D gradient echo technique (TE = 2.8 ms, TR = 9 ms, alpha=20°, FOV = (13 x 13) cm).

Results:

The 2-element array provides depth penetration suitable for laryngeal imaging. Axial and reformatted coronal views shown in Figure 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 cartilage, arytenoid cartilages and cricoid cartilage are clearly visible (Figure 2).

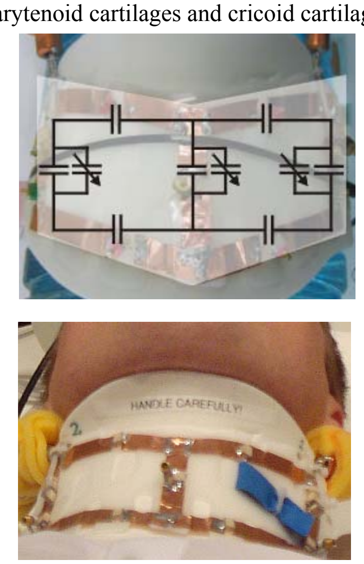

Figure 1: Geometry, basic design **(top)** and positioning without housing **(bottom)** of the 2 element TX/RX array tailored for laryngeal and vocal fold imaging at 7.0 T.

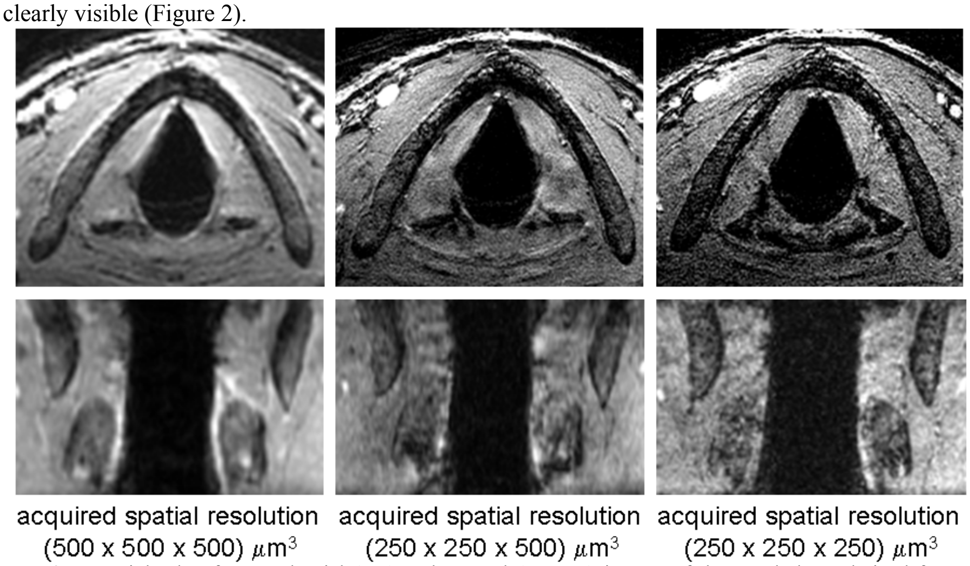

Figure 2: T_1 weighted, reformatted axial **(top)** and coronal **(bottom)** images of the vocal shape derived from 3D acquisitions using an spatial resolution of **left)** isotropic (0.5 x 0.5 x 0.5) mm^3, **middle)** anisotropic (0.25 x. 0.25 x 0.5) mm^3 and **right)** isotropic (0.25 x 0.25 x 0.25) mm^3. Thyroid cartilage, arytenoid cartilages and cricoid cartilage are clearly visible.

Discussion

The 2-element laryngeal array was found to meet the needs of isotropic, 3D, high 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 and flexibility. The new 2-element coil exhibits a significant SNR advantage over volume coils commercially available for 7.0 T systems. We anticipate using this setup in further volunteer and patient studies to gather static and semi-dynamic training and reference data to be used in a finite-element model of phonation functions. Looking forward, this synergy between an imaging and computational approach offers several new insights into the anatomy and physiological mechanisms during *in-vivo* phonation including (i) detailed mapping of the subglottal flow channel (ii) determining accurate geometric parameters of subtle anatomic structures including ventricular folds and arytenoid cartilages, (iii) detection of muscle bonding points and their inclusion in the larynx model, (iv) simulation and MRI based monitoring and verification of muscle controlled movements of the laryngeal cartilages, (v) imaging and simulation of phonatory maneuvers which all have been elusive to date. This requires extra synchronization of data acquisition with laryngeal and vocal fold motion, for which the subject's voice might serve as a triggering sound source for 3D-imaging of laryngeal tissues, vocal tract or other organs involved in speech and voice production.

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.