Relaxometry and Contrast Optimization for Laryngeal Imaging at 3 Tesla

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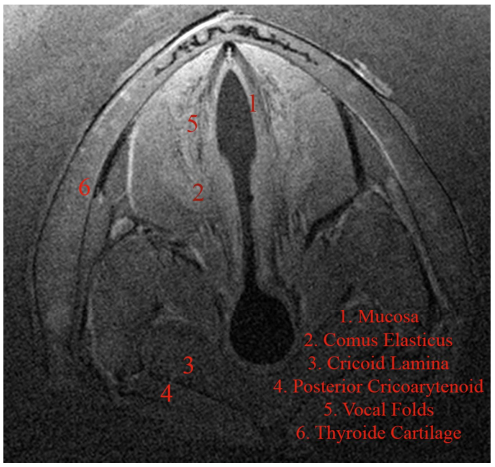
Introduction: Accurate models of vocal fold biomechanics and vibration can be used to study voice physics and to guide clinicians in their choice of treatment options as they attempt to restore or preserve voice quality in persons suffering from vocal or speech disorders. The development of engineered tissue and voice prostheses to replace damaged vocal fold tissues could benefit from these models. In addition, post-operative function and voice quality can be studied in order to guide phonosurgical interventions. The development of accurate models of vocal fold biomechanics would benefit from high-resolution 3D images with sufficient contrast between the various tissues of interest. While CT has been explored to develop these models in the past, it suffers from very limited soft-tissue contrast for differentiating the component tissues of the larynx.

In this study, we designed and built a 2-channel phased-array receive-only coil for high-resolution imaging of the larynx. The coil was tested on an excised pig larynx. T_1 and T_2 relaxometry was performed on an excised pig larynx to understand the MR signal characteristics of various tissues in the larynx. These values were then used to choose optimal sequence parameters for maximizing contrast between the comus elasticus tissue and the mucosa tissue, two tissues that are important (but difficult) to distinguish for accurate biomechanical modeling of laryngeal function.

Figure 1: Excised pig larynx with tissues labeled.



Methods: A custom 2-channel receive-only phased array coil was designed to lie in close proximity to the larynx, improving signal detection across the tissues of interest. The coil was tested on an excised pig larynx set in agarose gel to minimize susceptibility artifact. T_2 measurements were then performed on the pig larynx using a single-echo spin-echo sequence with TEs of 17, 30, 45, 75, 90, 120, and 200ms. A variety of tissues were segmented in the images (mucosa, comus elasticus, cricoid lamina, posterior cricoarytenoid, vocal folds, and thyroid cartilage), and average T_2 values calculated for each tissue using a simple monoexponential fit. T_1 measurements were then performed using an inversion-recovery sequence with TR/TE=5000/5.23 ms and inversion times TI = 50, 300, 700, 1200, and 2000 ms. Tissues of interest were again segmented, and average T_1 values calculated using a standard monoexponential model of T_1 recovery.

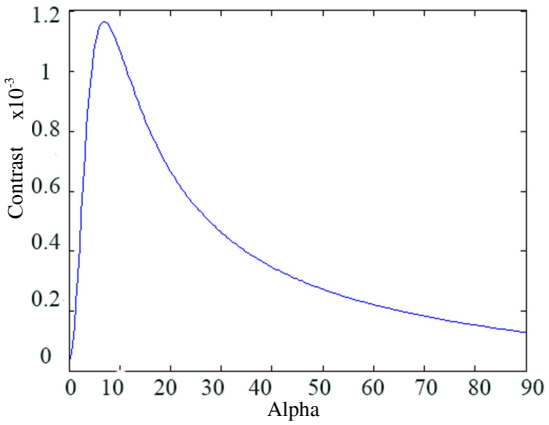
Following these measurements, a Bloch simulation of a 3D FLASH sequence was used to optimize the contrast for high-resolution 3D imaging of the larynx. The most difficult tissues to distinguish due to their relatively similar T_1 and T_2 values are mucosa and comus elasticus. A numerical optimization algorithm was used in conjunction with our measured T_1 and T_2 values for these two tissues and the Bloch simulation in an attempt to identify sequence parameters that maximize the contrast between mucosa and comus elasticus.

Results: Figure one shows a high-resolution image of the excised pig larynx with the various tissues of interest labeled. Table 1 summarizes the relaxometry results for each tissue. The T_1 and T_2 values for the cricoid lamina tissue falls in the range given in the literature for cartilage.[(1)] T_1 and T_2 measurements for most of the remaining tissues have not been previously reported at 3 Tesla. Ultimately, we hope to produce high-resolution images of the larynx in vivo using respiratory gating to minimize motion artifact. A very short TR is thus desirable to minimize acquisition time during each respiratory cycle. At TR/TE = 3.6/1.8 ms (a reasonable parameter set for 3D FLASH at the resolution and FOV we hope to achieve *in vivo*), our simulations showed that a flip angle of 9 degrees maximizes contrast between the mucosa and the comus elasticus tissues (Figure 2).

Tissue	T2 (ms)	T1 (ms)
Mucosa	110.2+/- 16.3	1266.6+/- 57.8
Comus Elasticus	79.3+/-9.8	1318.8+/-59.9
Cricoid Lamina (cartilage)	33.4+/-8.2	1023+/-74.6
Posterior Cricoarytenoid	33.5+/-5.4	965.9+/-39.2
Vocal Folds	59+/- 7	1130.5+/-128.2
Thyroide Cartilage	67.7+/-8.7	991.2+/-13.5

Table 1: Pig larynx model T_1 and T_2 measurements at 3T in milliseconds (value +/- standard deviation)

Figure 2: Signal Difference Between the Mucosa tissue and the Comus Elasticus tissue for a 3D Flash Sequence



Conclusion: Accurate models of vocal fold biomechanics require high-resolution 3D images with excellent soft tissue contrast. In this study, we were able to demonstrate high-resolution laryngeal imaging at 3 Tesla in an excised pig larynx using a custom laryngeal phased array receive-only coil. We then used the coil to perform high-resolution relaxometry on an excised pig larynx to obtain average T_1 and T_2 values of the critical tissues for modeling laryngeal function. These values were used to optimize sequence parameters for maximizing contrast between difficult-to-distinguish tissues in the larynx.

References

[1] Gold GE, Han E, Stainsby J, Wright GA, Brittain J, Beaulieu C. Musculoskeletal MRI at 3.0T: relaxation times and image contrast. Am J Neuroradiol 2004;183:343–350.