3D Modeling of Laryngeal Structure via High-Resolution MRI Segmentation and Histological Analysis

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Abstract

To better understand both the 3D geometric structure of human laryngeal anatomy and the structural attributes of its many tissue components we have acquired high-resolution magnetic resonance (MRI) spatially calibrated images of 9 adult excised human larynx specimens. Additionally we have conducted histological analysis of those same 9 larynx specimens via H&E and Mallory's Trichrome staining techniques to distinguish between, muscle, cartilage, collagen, elastin, and connective tissue. When analyzed together the MR images and the histological slides allow correlation between MR image contrast variation and specific tissue composition. Detailed information regarding vocal fold tissue composition and histological geometry provided by this study will enable laryngeal modelers to select more appropriate and life-like materials with which to construct synthetic vocal fold models. This study may also lay early groundwork in the field of voice research, specifically, the engineering of voice prostheses to be used in laryngoplasty procedures.

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Keywords

MRI Segmentation, Larynx Histology, High Resolution MRI, Laryngeal Geometry, Larynx Model

1. Introduction

In many clinical research scenarios it is appropriate to use a model to understand the anatomy and physiology of the body when the particular area of interest is difficult or dangerous to access in vivo. Where truly accurate life-like anatomical models are available it is appropriate to use them to determine the outcome of experimental surgical procedures without risking patient safety. The anatomical location of the human vocal apparatus renders it particularly difficult to access for the measurement of pathological changes, damage assessment, and surgical intervention in patients suffering from phonation related pathologies. Because of it's difficult to access location, laryngeal modeling would serve as a very valuable tool for the advancement of modern phonosurgery.

To better understand both the 3-D geometric structure of human laryngeal anatomy and the structural attributes of its many tissue components, we have acquired high-resolution magnetic resonance (MR) spatially calibrated images of nine adult excised human larynx specimens. Additionally we have conducted histological analysis of those same nine larynx specimens via H&E and Mallory's Trichrome staining techniques to distinguish between, muscle, cartilage, collagen, elastin, and connective tissue. When analyzed together the MR images and the histological slides allow correlation between MR image contrast variation and specific tissue composition. Detailed information regarding vocal fold tissue composition and histological geometry provided by this study will enable laryngeal modelers to select more appropriate and life-like materials with which to construct synthetic vocal fold models. This study may also lay early groundwork in the field of voice research, specifically, the engineering of voice prostheses to be used in laryngoplasty procedures.

2. Source of the Data

Following the removal of all exterior excess muscle all nine larynx specimens were imaged using a two-dimensional T2 weighted turbo-spin echo sequence. The sequence was implemented on a 3T Siemens whole-body scanner (Siemens Medical Systems, Erlangen, Germany) with a 32-channel head coil. The field of view (FOV) of the scan is 200 mm (readout) x 141.5 mm (phase) x 1 mm (slice-thickness) and the acquisition matrix was 896 (readout) x 634 (phase encode) and 42 in slices direction with interleave acquisition pattern (12 slices was used for oversample) which yields the voxel size equals to 0.22 mm x 0.22 mm x 1 mm. Because of the small voxel size, nine averages were employed to obtain an adequate signal-to-noise ratio (SNR) which made the total acquisition time about 55 minutes. The TR/TE = 5000/89 msec flip angle is 150 degree. Other acquisition parameters were; turbo factor = 12, and readout bandwidth = 328 Hz/pixel. Fast mode RF pulse was selected and the slice distance was 1 mm. Raw dicom images and models generated using Amira FEL Inc. software are provided in this work.

3. Description of the Data

Nine 3-D models of human laryngeal structure were generated via high resolution MR image segmentation. Additionally, a short video depicting the 3-D nature of our models can be assessed online as supplementary material accompanying this publication. The 3-D structure and relative spatial location of the vocal fold mucosa, thyroid cartilage, cricoid cartilage, arytenoid cartilage, vestibular space, vocal ligament, intrinsic laryngeal muscle, and fascial spaces can be clearly observed models as well as their positions relative to one another in both the videos and the Amira.

4. Data files

Data from nine larynges are available in 'zip' files. There are two folders for each larynx. The folders entitled "Larynx # Amira model" contain the 3-D models generated using Amira FEL

Inc. software for each larynx. The second set of folders entitled “Larynx # dicom” contain the raw dicom images for each larynx. The larynges are numbed according to the cadaver donor number and are not in numerical order.

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Use Agreement

The scripts, images and text are open to use by the public as a service and part of the National Resource of Laryngeal Data; with initial startup funds supported by the National Institute of Deafness and other Communicative Disorders (DC009616) and the National Center for Voice and Speech. The scripts, images, model and text enclosed in this memo and accompanying this memo are open to use by the public as a service of the NRLD. However, we ask the reader to respect the time and effort put into this manuscript and research. If the text, images, or included scripts are used, the user agrees to reference to this document, the NRLD, and the source of the original data. We also ask the users to consider contacting the original contributors of the data and give them the right of refusal to (1) participate on papers using the data and (2) have their supporting project acknowledged. The user agrees to freely share with the NLDR any extension software build on the data contained.

Revisions

1.0 Mark Berardi: main document and content (February 10, 2016)