# Solid CAD Models of Human Laryngeal Cartilage

# Created from Selbie *et al.*

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## Abstract

Finite element modeling of the human laryngeal system is dependent on accurate models of the geometry. Using magnetic resonance images (MRIs) of a human laryngeal cartilage, CAD solid models were created.

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**Keywords**: laryngeal cartilage, CAD model, MRI, thyroid, cricoid, arytenoid.

## 1. Introduction

Understanding the morphology of the laryngeal framework is crucial to mapping laryngeal function, as well as for more accurate quantitative biomechanical modeling of voice disorders (Farley, 1996; Farley & Thomson, 2011; Hunter, Titze, & Alipour, 2004; Titze & Hunter, 2007). Accurate dimensions of all structures of the larynx are required, particularly dimensions of those structures which describe function in mechanical terms (e.g., laryngeal muscle orientation, cartilage length/width, and joint size/range).

Because of the difficulty in obtaining and performing experiments on the human larynx, Magnetic Resonance Imaging (MRI) has become a useful tool in obtaining anatomical information in both live subjects and donated samples. In the final form, such images can be used to create geometric shapes.

The purpose of this report is to provide the computer solid models (CAD) created from images of human MRI scans of the laryngeal cartilage. The goal is to present these images with sufficient detail for future researchers to use the results (Hunter & Hunter, 2005).

## 2. Creating the Models

For the current report, 128 MRI images of human larynges were used. As discussed in NRLD#000001 (Hunter & Thomson, 2011), images were obtained directly from authors (Selbie, Gewalt, & Ludlow, 2002; Selbie, Zhang, Levine, & Ludlow, 1998). More detail about creating three-dimensional CAD models from images is presented in NRLD#000002 (Thomson & Hunter, 2011) and NRLD#0000004 (Mau, 2011).
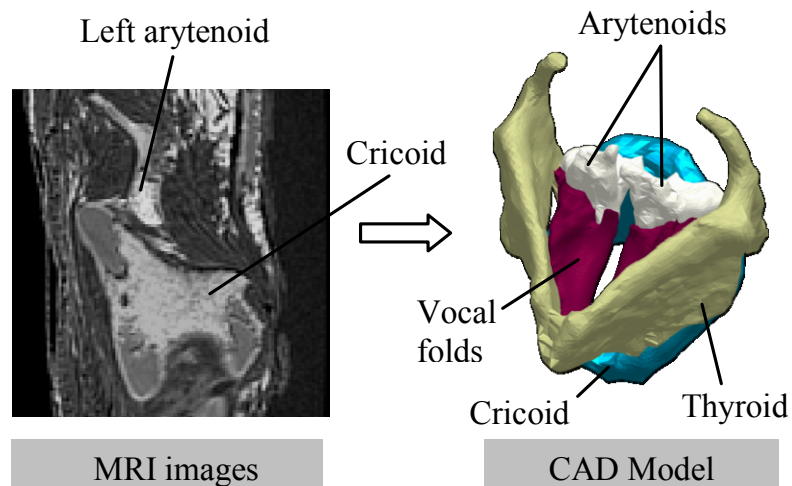


Figure 1: MRI-based synthetic larynx model fabrication process

Commercial MRI and three-dimensional software packages (Velocity2 and Pro/Engineer, respectively) were used to import the images. Grayscale thresholding techniques were used to identify and extract three-dimensional representations of the vocal folds, as well as the cricoid, thyroid, and arytenoid cartilages. Scaling of the images was done in consultation with cartilage data (Hunter & Titze, 2005a, 2005b; Kim, Hunter, & Titze, 2004). Images and eventual solid models were output as STEP files.

## 3. Data files

### 3.1 Files

Three sets of files are presented: [1] a solid shell version; [2] a surface version; and [3] a media movie for visualization of the solid file. The media file is in Windows Media Video format. Besides the major cartilages of the larynx (arytenoid, cricoid, thyroid), a CAD rendition of the vocal folds which matches the thyroid geometry file was added. These sets of files were compressed into corresponding 'zip' files called SolidShell_CAD_stp.zip, Surface_CAD_stp.zip, and CAD_moviefiles_wmv.zip respectively.

Table I. Accompanying files.

| Structure | Solid shell CAD | Surface CAD | Media |
|---|---|---|---|
| Arytenoid Cartilages (paired) | Arytenoid_SolidsShells.stp | Arytenoid_Surfaces.stp | ArytenoidCartilage.wmv |
| Cricoid Cartilage | Cricoid_SolidsShells.stp | Cricoid_Surfaces.stp | ChricoidCartilage.wmv |
| Thyroid Cartilage | Thyroid_SolidsShells.stp | Thyroid_Surfaces.stp | ThyroidCartilage.wmv |
| Vocal Folds | -NA- | VF_Surfaces.stp | VocalFolds-CT.wmv |

### 3.2 Reading Files

The format of the files is a CAD format STEP (stp) file. While there are many CAD formats, STEP files are the international standard for computer-interpretable representation and exchange of product manufacturing information (ISO 10303). Commercial CAD programs will be able to import these files. There are also free, open-source, CAD programs which can open and visualize the STEP file (e.g., FreeCAD was used in making the media visualizations of the files).

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# Acknowledgements

# 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 (supported by the National Institute of Deafness and other Communicative Disorders). 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 this document, the NRLD, and the source of the original data. We also suggest that the user contact 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     Eric Hunter: Main document; Scott Thomson provided the CAD models (April 2012).
2.0     Laura Hunter: Imported into new template, technical writing review (April 2015)