Detailed three-dimensional anatomic characterization of the canine posterior cricoarytenoid, lateral cricoarytenoid, interarytenoid, thyroarytenoid.

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Abstract

Detailed muscle information is valuable for developing increasingly complex biomechanical models of the larynx (e.g., size, direction, structure, shape at origin and insertion). This report contains data of four male and four female canine larynges, specifically presenting details of the intrinsic abductor and adductor musculature of the canine larynx: the posterior cricoarytenoid, the lateral cricoarytenoid and the interarytenoid muscles. Also presented are three-dimensional representations of the four to five muscle bundles of each muscle. From this resource, models can be developed to facilitate the study of the influence of the subglottis in voice production. Updates to this memo can be downloaded at http://www.vocalfolds.org.

Keywords: laryngeal muscles, posterior cricoarytenoid, lateral cricoarytenoid, interarytenoid, thyroarytenoid, vocal folds

1. Introduction

Laryngeal muscles, with the surrounding cartilages and joints, posture the vocal folds via length change and abduction/adduction. Therefore, they are key to overall health (ventilation, swallowing, and effort closure of the airway[1]) and voice (vocal onset, self-sustained oscillation, intensity, and pitch[2-7]). Knowledge of laryngeal structure (e.g., cartilages and soft tissue) and musculature (e.g., intrinsic laryngeal muscles' orientation, strength, and type) is needed to understand the mechanisms of posturing and phonation. Previous studies[8],[9-12] of laryngeal muscles have largely been whole muscle descriptors, focusing on quantifying average size (i.e., length and cross-sectional area), overall orientation, and mechanical characteristics (e.g., stress-strain relations and contraction times).

Studies like these have provided a valuable foundation for understanding laryngeal muscles. However, whole muscle studies cannot be used to explain why portions of individual laryngeal muscles have specific posturing functions[13-15]. Neither can they be used to explain how to compensate for some pathologies or post-operative conditions which exclude portions of an individual muscle viable for laryngeal control[16;17]. Further, inter-muscle spatial relations must be known to model conditions like laryngeal asymmetry, a common symptom of numerous laryngeal pathologies.

Specific laryngeal information is particularly important for laryngeal models (of both phonation and posturing), the goal of which is often to lay the foundation to predict vocal injury[18]. If refinements were made to the basic assumptions and the anatomical information on which these models are based, the results of small variations in glottal therapy and phonosurgical interventions (such as vocal fold medialization) could be accurately and non-invasively simulated[19]. Thus, detailed distributed muscle information, which would enhance the understanding of vocal fold mechanics, is essential.

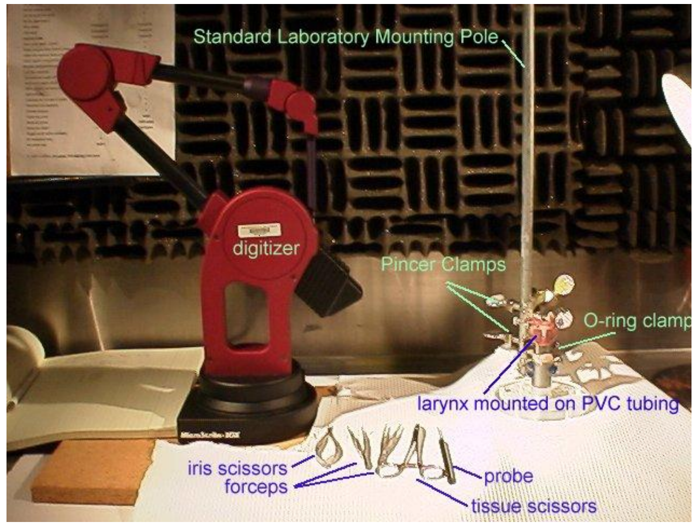
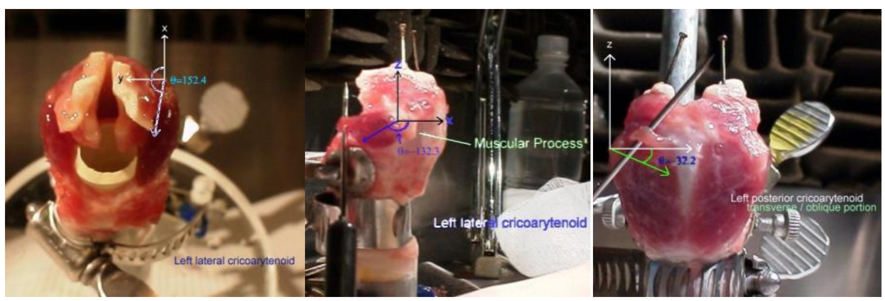


Figure 1. Previously unpublished image of experimental setup.

The goal of this manuscript is to present fibre bundle orientations of the canine PCA, LCA, and IA. Specifically given are laryngeal muscle bundle origin and insertion points in three dimensions, and corresponding average muscle area.

2. Data

No new data muscle data were collected for the current report. Rather, existing data from the PCA, LCA, and IA from four male and four female canines were taken from the NCVS archives and lab notebooks.



(a) (b) (c)

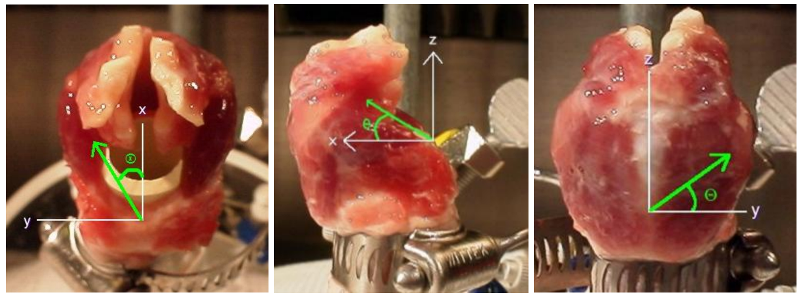
Figure 2. Dissection and orientation of muscle bundles. (a) left LCA. (b) left LCA and muscular process. (c) left PCA.

Laryngeal samples were excised postmortem. No animals were sacrificed for the work as the samples were obtained from previously sacrificed animals. Each larynx was first dissected to expose the muscles of interest. The larynx was mounted by securing part of the trachea over a piece of tubing. The cricoid cartilage and arytenoid cartilages were firmly fixed in the cadaveric position such that rotation and translation were eliminated.

Spacial digitation was accomplished using a MicroSribe-EDX digitizer (Immersion Corp) with resolution of 0.2 mm, Figure 1. From these samples, muscle bundles were isolated and the coordinates of origin and insertion were recorded (Fig 2). On average, four to five muscle bundles were measured for the IA, while eight to ten were measured for the LCA


Figure 3. Picture of dissected muscles from a sample.

and PCA (e.g., Fig.3). The mass of each bundle was obtained by weighing each bundle to estimate the cross sectional area[20]. Only average muscle length, average cross-sectional area and average direction were reported previously[8].



(a) (b) (c)

Figure 4. Coordinate system with cricoid cartilage as the anchor. (a) xy plane. (b) xz plane. (c) yz plane.
x: anterio-posterior, anterior or frontward positive;
y: medio-lateral, rightward positive;
z: inferio-superior, superior or upward positive),

Raw three-dimensional data were recorded in terms of a common coordinate system, Fig 4. The coordinate system was described with respect to the cricoid cartilage. The raw data were read from the original text files and formatted as EXCEL Spreadsheets for easy access (canine1.xls, canine2.xls, canine3.xls, canine6.xls, canine7.xls, canine8.xls, canine9.xls). These spreadsheets have the data from the 3-D digitizer in x, y and z coordinates. Most bundles were digitized twice before removal, so the final x, y, z origin and insertion coordinates were an average of the multiple measures. For orientation, each file contained an 'origin' coordinate and a 'z-line' set of points (which illustrate the z direction from the origin), and a 'pure x' which was a coordinate in the x direction. From these, the rest of the data could be translated to the origin. Bundles were labeled by the muscle then the bundle number. For example 'lpca.1' represents the first bundle of the left LCA muscle. The weight of the bundle (in grams) was also given, assuming the density of muscle tissue of 0.001043 g/mm^3 the area could be calculated. Finally, the vocal process and the muscular process were labeled as *vp* and *mp* respectively.

3. Using the Data

Along with the tables, a spreadsheet is provided, along with Matlab scripts. The spreadsheet (MineckMuscleInfo.xls) shows where the data exist in other spreadsheets. With specific row and column numbers the Matlab script canine.m can plot the data in 3-D plots. As currently uploaded, running the canine.m file with the other files in the same directory will load the orientation information from canine 9 and plot in a three-dimensional plot which can be rotated. Muscle data can then be plotted onto the plots using additional scripts. After running canine.m (and leaving the figure active in Matlab), the get9rlca.m script will draw the right LCA muscle origin and insertion surfaces in the plot illustrating how that may be done.

4. Accompanying Files

File	Description
TablesFromPaper.xls	Spreadsheet version of the tables in Mineck et. al.[8].
canine1.xls	Data from specimen #1, containing bundle origin, insertion, mass and origin data
canine2.xls	Data from specimen #2, containing bundle origin, insertion, mass and origin data
canine3.xls	Data from specimen #3, containing bundle origin, insertion, mass and origin data
canine5.xls	--data file not found in the archives, to be uploaded when found--
canine6.xls	Data from specimen #6, containing bundle origin, insertion, mass and origin data
canine7.xls	Data from specimen #7, containing bundle origin, insertion, mass and origin data
canine8.xls	Data from specimen #8, containing bundle origin, insertion, mass and origin data

canine9.xls	Data from specimen #9, containing bundle origin, insertion, mass and origin data
MineckMuscleInfo.xls	Location of orientation data for #3,6,7,8,9.
canine.m	Matlab script that loads the orientation info from MineckMuscleInfo.xls and plots.
get9rlca.m	Loads LCA muscle bundle information and plots in 3-D.
getMineck_f.m	Dependent matlab script
plotBundles_f.m	Dependent matlab script
plotSurface_f.m	Dependent matlab script
plotMuscles.m	Dependent matlab script

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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 (supported by the National Institute of Deafness and other Communicative Disorders, and hosted by 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 Eric Hunter: Main document (June 2012)