Controlled Testing Enclosure for Measuring Larynx Phonation Pressure

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Abstract

Dr Jack J Jiang has developed an airflow redirection device which non-invasively measures sub-glottal pressure, an essential factor in the evaluation in laryngeal health. Currently, this device noninvasively collects data from human subjects. In order to perform pressure measurements more directly, an apparatus has been developed to test with an excised canine larynx. However, the larynx in this apparatus does not currently have a way to interface with the airflow redirection device. The client needs a controlled testing enclosure that is airtight, is able to interface with the canine larynx and airflow device, and manipulates the larynx shape during testing. An airtight, transparent, acrylic enclosure has been fabricated with a translating plate mechanism that is able to move in the x-y-z directions. This mechanism changes the shape of the laryngeal folds to produce various phonation sounds. Testing has shown that the enclosure has a final volume of 252.4 cm3. In a submergence test, the average volume displaced before failure of the airtight seal was 566.83 ± 7.252 cm^3.

Motivation

Measurement of sub-glottal pressure

- Pressure needed to produce phonation
- Evaluation of laryngeal health
- Diagnostic potential

Novel new device developed

- Uses airflow redirection
- Noninvasive
- Minimal patient training required
- Method needed to test device

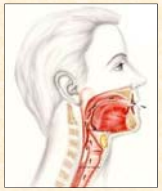


Figure 1. Position and anatomy of larynx in human body [4].

Current phonation testing device

- Uses excised canine larynxes
- Cannot measure sub-glottal pressure

Our Objective

- Create an interface between the two devices
- Only used to test airflow redirection device
- Must meet all design criteria

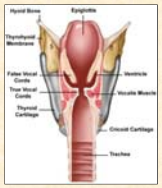


Diagram of the human larynx and surrounding organs [5]

Current Apparatus

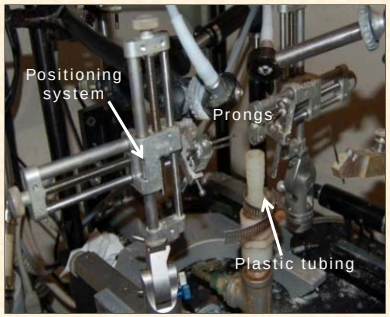


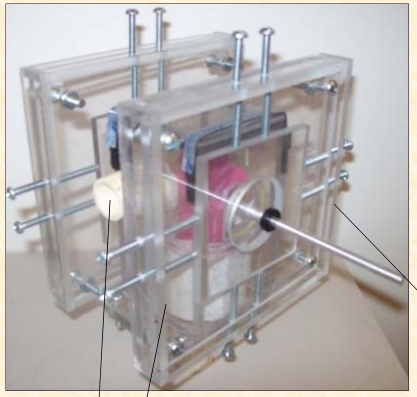
Figure 2. Current apparatus used by client which tests excised canine larynges.

Testing Environment:
- Camera view from above
- Larynx sits on plastic tubing
- Prongs manipulate larynx shape
- Positioning system of threaded rods
  - -move prongs in x-y-z directions
- Separate mouthpiece connects to airflow redirection device
- Interface enclosure with plastic tubing and mouthpiece

Design Criteria

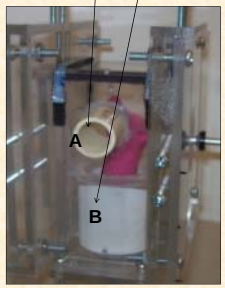
- Interface between excised larynx and airflow device
- Compatible with current testing apparatus
- Airtight, rigid
- Approximate volume = 200 cm^3
- Withstand pressure up to 100 cm H_2O
- Transparent
- Mechanism to access larynx during testing
- Manipulate laryngeal folds
  - Up to 3 cm in x-y-z directions

Final Design



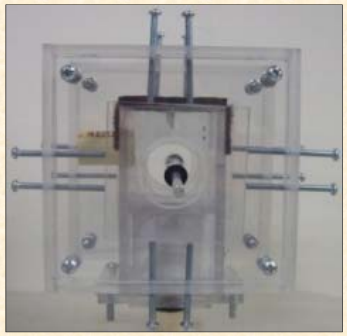
Overall Enclosure
- 0.22 inch thickness acrylic box structure
- Dimensions = 5 x 5 x 11 cm^3
- Positioning mechanism for x-y-z directions
- Completely rigid
- Multiple interfaces ensure compatibility with existing testing apparatus and procedure

Cost Analysis
- Total for prototype = $99.34
- PVC, larynx mount donated by client

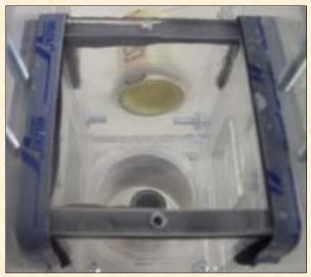


(A) PVC – mouthpiece interface
- Solvated directly to enclosure
- Maintains airtight seal

(B) PVC – larynx surrounding
- Creates dead space
- Minimizes volume



Translating Plate
- Moves 3 cm in x-y plane
- Screws for incremental positioning
- Larger plates allow for greater freedom of motion in x and y directions
- Sliding rod inserts into rubber lined tube for z-direction manipulation
- Water-based lubricant
- Removable outside plates allow for cleaning and reapplication of lubricant



Removable Lid
- Weather stripping lining
- Larynx hydration access
- Velcro straps

Larynx mount
- Removable
- Easy access to clamp larynx
- Multilayered for stability
- Interfaces with pseudo-lung

Testing

Volume Test
- Fill enclosure with water
- Water weighed using balance
- Use conversion 1g H_2O = 1cm^3

Total Volume (cm^3)	Volume – Larynx (cm^3)
252.4 ± 0.447	215.4 ± 0.447

Pressure and Airtight Seal Test
- Submerged enclosure in water bath approximately 8.5 cm
- Measured depth of submergence before airtight seal failed
- Displaced volume corresponds to internal box pressure
- Average = 566.83 ± 7.252 cm^3

Trial	Depth of Submergence (cm)	Volume Displaced (cm^3)
1	8.4	547
2	8.7	568
3	9	589
4	8.6	561
5	8.9	582
6	8.5	554

Future Work

Potential Improvements:
- Install convenient hydration mechanism
  - Consider one-way valve to fit nozzle of saline bottle
- Interface translating plate to client's current positioning system
- Design storage case to hold device when not in use
- Mill rubber gasket around translating plate to reduce the amount of lubrication needed

Further Testing:
- Test erosion effects of water-based vs. oil-based lubricants
- Perform a quantifiable pressure test
- Effects of pressure loss on expected data measurements

References

[1] Baggott C, Yuen A, Hoffman M, Zhou L, and Jiang J. Estimating Subglottal Pressure via Airflow Redirection. *Laryngoscope. 2007; 117:1491-1495.*

[2] Rieves A, Regner M, and Jiang J. Phonation Threshold Pressure Estimation Using Electtroglottography in an Airflow Redirection System. *Laryngoscope. 2009; 000: 1-6.*

[3] Pon, S. (2000, October 25). *Medical calcultors: pressure conversion*. Retrieved from http://www-users.med.cornell.edu/~spon/picu/calc/pressure.htm

[4] Grolman, W. *Normal Larynx*. Digital image. *Ear, Nose & Throat (ENT) site*. Oto-Rhino-Laryngology, 31 May 2001. Web. 3 Dec. 2009. <http://www.orl.nl/laryngectomy/larynx.htm>.

[5] Gull, John. *The Larynx or "voicebox"* Digital image. *Anatomy of the voice*. John Gull. Web. 3 Dec. 2009. <http://www.johngull.co.uk/Anatomy%20of%20the%20voice.htm>.

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