

# Unilateral Human Vocal Fold Stiffness

First applicant name: John Doe  
First applicant email and RouteY login: johndoe@byu.edu  
Mentor name and department: Jane Nobody, MECHANICAL ENGINEERING (E&T)

## Goal/Purpose

The purpose of the proposed research is to study the effects of unilateral vocal fold paralysis on voice production.

## Importance of Project

Unilateral Vocal Fold Paralysis (UVFP) is a condition in which one of the vocal folds is immobilized and thus cannot close. UVFP is caused by injury to parts of the brain or nerves that control the vocal fold muscles. Most often this is a result of trauma, disease, or severance of a nerve during surgery. UVFP does not present respiratory problems, but it does greatly affect a person's ability to speak. This condition causes a hoarse, breathy, and soft voice as well as difficulty in swallowing because the vocal folds are unable to close all of the way (Yoskovitch and Kantor, 2001). There are surgical procedures available to restore normal speech capability. The way this is achieved is by vocal fold medialization (which is a process of repositioning the immobilized vocal fold closer to the active vocal fold). Two common ways of achieving this is through injection medialization (injecting a substance into the vocal fold [Harries, 1996]) or through medialization laryngoplasty (implanting artificial material into the larynx [Rammage, 2001]). Both of these procedures introduce material into or near the area of vibration of the vocal folds. Atrophy of the vocal fold muscles (caused by immobilization) and the addition of new materials into the area of the vocal fold both have an effect on the stiffness of the vocal fold. The purpose of this project is to study the effects of the change in stiffness of the vocal fold due to this introduction of new material during medialization.

## Main Proposal Body

The purpose of the proposed research is to study the effects of UVFP on voice production. Recently Dr. Thomson and his research team have worked to develop a synthetic silicone model of the vocal folds. The model consists of two layers of varying stiffness which simulate the anatomy and stiffness of human vocal fold tissue. Stiffness variation is achieved by varying the mixing ratio of the silicone rubber mixture. This model was developed by extracting vocal fold geometry from MRI images, importing those 3-D images into a CAD program (ProE), having those rapid prototyped and creating molds from the rapid prototype models. A three-part silicone rubber mixture is poured into the molds and cures to form the vocal folds. We use these vocal fold models to study such things as: the acoustics of the sound radiated by the vibrating model, the minimum pressure required to sustain vibration, the motion of the model, and airflow.

High-tech tools listed below will be utilized to gather data that will be used to study and increase understanding of the effects of UVFP on voice production. This will be accomplished by varying the stiffness of one vocal fold. The stiffness of the base (or body) of the fold will be varied to simulate the effects of medialization laryngoplasty and muscle atrophy. The stiffness of the outer layer (or cover) will be varied to simulate the effects of injection medialization. The variation of stiffness of the layers of the model will be achieved by varying the mixing ratio of the 3-part silicone rubber mixture that is poured into the molds to make the vocal fold models. As the rubber is poured into the molds, excess rubber will be poured into small circular tubes. Those circular samples of the rubber will be tested using an Instron machine to find the Young's modulus of the rubber used in the vocal folds. The vocal fold models will then be mounted in acrylic plates, the plates will be brought together to bring the two model vocal folds in contact and pressurized air

will be forced between the folds using the current set up in Dr. Thomson's research lab. A particle imaging velocimetry system will be used to produce a vector field which will visually show the jet stream of the airflow coming out of the vocal folds. The high speed imaging camera will be used to monitor the motion of the model. A pressure gage will be used to determine the minimum pressure required to sustain vibration. These experiments will provide data which will increase our understanding of the effects material asymmetry has on the mechanics of the vocal folds during speech production.

This project will increase understanding of how UVFP affects speech. The clinical significance of this project is that it will lay the groundwork for improving current procedures to treat this condition and ultimately provide improved solutions for those who suffer from UVFP. These improvement can, as stated by Dr. Thomson, lead to "improved clinical care, improved medical procedures, and an increased awareness of individuals in the workforce who rely on voice use."

### **Anticipated Academic Outcome**

It is anticipated that the results of this project will be published in academic journals such as the Journal of Biomechanics, the Acoustical Society of America Journal and The Journal of Voice. It is further anticipated that these discoveries will be shared in various conferences such as the American Society of Acoustics conference, the American Society of Biomechanics conference and the American Society of Mechanical Engineers Bioengineering Division meeting.

### **Qualifications**

Dr. Thomson graduated from Purdue University with a Ph.D. in mechanical engineering. His dissertation was on vocal fold modeling. His research as a professor at BYU has continued the study of the vocal folds. He has presented at academic conferences numerous times discussing his research. He has also published many articles in academic journals discussing the findings of his research.

Dr. Thomson taught my fluid dynamics class during the winter semester of this year. I became very interested in his research and expressed my interest in being involved with his research group. I have been working as a research assistant since January of this year. All of my education up to this point has helped me prepare for this project. Most helpful in my preparation for this project has been my course work in Physiology, Fluid Dynamics, Instrumentation, and Intermediate Materials. Additionally, I have been a member of the BYU Biomedical Engineering Club for the past two years and am currently one of the club co-presidents. Experience as an intern for a Biomedical Engineering company called Cytoc Surgical Products during the summer of 2006 has further prepared me for the project ahead.

### **Project Timetable**

Our research up to this point has led to the beginnings of this project and preliminary work is already under way. The following is the planned outline that will be followed to assure the success of this project:

Oct 2007 Become acquainted with computer software and hardware (including PIV and high speed imaging camera)  
Nov 2007 Prepare vocal fold models for analyses  
Dec 2007 Develop a procedure for adjusting material properties (specifically stiffness)  
Jan 2008 Perform analyses and make observations of development  
Feb 2008 Refine model and repeat analyses  
Mar 2008 Prepare reports and presentations of observations and conclusions  
Apr 2008 Present and publish findings

## **Fit With BYU's Mission**

This project is expected to fulfill BYU's mission, aims and objectives in the following ways:

- 1) "Spiritually strengthening" through a deeper understanding of and appreciation for the human body, the greatest of all of God's creations
- 2) "Intellectually enlarging" in consequence of focused research and scientific discovery
- 3) "Character building" as a result of the difficult and demanding nature of the project
- 4) Experience provided by this project will be valuable preparation for a future career in the biomedical engineering industry, where I feel I can best pursue the lifelong goal of "learning and service"
- 5) This project will "educate the minds and spirits" of others, "advance truth and knowledge" and "extend the blessings of learning" to others through presentations and publications.

## **Sources**

Harries M. (1996). "Unilateral vocal fold paralysis: a review of the current methods of surgical rehabilitation." *The Journal of Laryngology and Otology*. 110, 111-116.

Rammage L, Morrison M, and Nichol H. Management of the Voice and Its Disorders Second Edition. Canada: Singular, 2001.

Rubin J, Sataloff R, and Korovin G. Diagnosis and Treatment of Voice Disorders. San Diego: Plural Publishing Inc, 2006.

Thomson S. (2004). Fluid-Structure Interactions within the Human Larynx, Ph.D. Dissertation, Purdue University, West Lafayette, Indiana.

Thomson S, Mongeau L, and Frankel S. (2005). "Aerodynamic Transfer of Energy to the Vocal Folds." *J. Acoust. Soc. Am.* 118, 1689-1701.

Yoskovitch A and Kantor S. (2001). "Cervical osteophytes presenting as unilateral vocal fold paralysis and dysphagia." *The Journal of Laryngology and Otology*. 115, 422-424.