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Do Patients With Gastroesophageal Reflux Disease (Gerd) Exhibit Vocal Fold Deficits Manifested In Physical Or Acoustical Abnormalities?

Emily L. Mingus
Cleveland State University

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EMILY L. MINGUS

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We hereby approve this thesis for

EMILY L. MINGUS

Candidate for the Communication Sciences and Disorders degree for the

Department of Health Sciences

and the CLEVELAND STATE UNIVERSITY'S

College of Graduate Studies by

____

Thesis Chairperson, Violet Cox, PhD., CCC-SLP

____

School of Health Sciences 5/2/22

____

Thesis Committee Member, Carol Spears., M.S., CCC-SLP

____

School of Health Sciences 5/2/22

____

Committee Member, Andrew Lammers, Ph.D.

____

School of Health and Sciences 5/2/22

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DO PATIENTS WITH GASTROESOPHAGEAL DISEASE (GERD) EXHIBIT VOCAL FOLD DEFICITS MANIFESTED IN PHYSICAL OR ACOUSTICAL ABNORMALITIES?

EMILY L. MINGUS

ABSTRACT

GERD is an esophageal disease that has both esophageal and extra-esophageal symptoms. Due to the acidic nature of GERD, there appears to be a disruption in the function of the tissues surrounding the area of the vocal folds. This study investigated the influence of GERD as it relates to voice and swallowing. Data were previously collected on twelve individuals, six with a medical diagnosis of GERD and six with no medical diagnosis of GERD, and analyzed. This included descriptive analysis of data points from a Visi-Pitch, Videostroboscopy, and Fiberoptic Endoscopic Evaluation of the Swallow (FFES). The objective measurements from the Visi-Pitch and descriptive information from the Videostroboscopy and FEES were then combined and compared based on the presence of a medical diagnosis of GERD, by the PI of the study and the co-investigator. Results showed changes in tissue ranging from trace to severe in both the GERD and no-GERD groups. Findings suggest a correlation between abnormal acoustical measures and changes in tissue. Trends were also found based on age, length of diagnosis, and level of severity of tissue changes in both groups. The results of this study could be significant in the clinical treatment of individuals with GERD and highlight the importance of objective data points, and an interdisciplinary team.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The field of speech-language pathology, like most medical professions, is constantly advancing. It is up to the individual clinician to ensure they remain competent and up to date on the most evidence-based practices. Gastroesophageal reflux disease (GERD) is one of those challenges that frequently confront medical professionals. Because of this, speech-language pathologists in medical settings must be aware of this increase as well as how it presents. This study aims to identify current trends of GERD and its effect on voice and swallowing. The study will also suggest some of the appropriate subjective and objective data points that the clinician may collect to treat patients holistically.

Gastroesophageal reflux disease: An Esophageal Disease

Gastroesophageal reflux disease, sometimes known as acid reflux, is the most common gastrointestinal swallowing disorder in the United States. It tends to affect 18% to 28% of the population with an estimated 13% of Americans using medications at least twice weekly (El-Serag et al., 2014). Once the food is fully masticated, it moves through the pharynx, passes the upper esophageal sphincter, enters the esophagus, and then through the lower esophageal sphincter into the stomach (*Digestive System*, 2021). GERD occurs when acid moves from the stomach into the esophagus. In some cases, the acid can also make its way back into the pharynx this is known as laryngopharyngeal reflux (LPR). GERD usually presents clinically with symptoms of heartburn and regurgitation, which are considered a part of esophageal syndromes. It can also present with extraesophageal manifestations, such as chronic cough, chronic laryngitis, asthma, chest pain, postnasal drip, or recurrent sinusitis. (*Gastroesophageal Reflux Disease (GERD) - Symptoms and Causes*, 2020). For the purposes of this study, the term GERD and LPR will be used synonymously as used in some current literature. In the United States, GERD is a general term to refer to a gastrointestinal swallowing disorder.

Many speech-language pathologists may not be aware of the impact of GERD/LPR on the voice and swallowing, and consequently, they may fail to make the connection during a routine voice or swallowing evaluation. The evaluation and management of patients who present primarily with extraesophageal reflux (EER)-related symptoms have been increasingly difficult due to a lack of reliable objective data showing the presence of GERD-related symptomatology and voice disorders. This is further complicated by GERD being an esophageal swallowing disorder and therefore out of the scope of practice of most speech-language pathologists. It is an SLP's responsibility, however, to note abnormal findings of the digestive tract as seen by imaging, and report those findings so that the patient may be referred to the appropriate medical professional (*Adult Dysphagia*, n.d.).

Depending on the presentation of the GERD, different treatment modalities may be required. The first type of treatment is medication. A patient might first complain of any of the symptoms outlined above to their primary care physician (PCP), who would typically prescribe a proton pump inhibitor (PPI) for the management of symptoms (Abdi et al., 2020). This medication works to stop the stomach from producing the acid which relieves extraesophageal symptoms including heartburn ((*Proton Pump Inhibitors*, n.d.). Physiological changes secondary to GERD may cause esophageal dysmotility; this in some cases, may require surgical intervention to strengthen the integrity of the lower and upper esophageal sphincters, to prevent acid from traveling back up to the esophagus (Sharma & Yadlapati, 2021). The regurgitation in some cases reaches the level of the pharynx, placing the patient at risk for aspiration. This is where the intervention of the speech-language pathologist may be required.

Dysphagia and GERD

Dysphagia a Latin term when broken down can be described as "dys" meaning disordered, "phag" meaning to consume, and "ia" a condition. Altogether, this means a condition with disordered consumption. Swallowing can be broken up into four phrases, oral preparatory, oral, pharyngeal, and esophageal. The oral preparatory phase is the stage at which the food is masticated. From there, the food is propelled posteriorly by the tongue. This is the oral phase of the swallow. The next phase is the pharyngeal phase where the pharyngeal constrictor muscles sequentially contract thus guiding the food to the esophagus where the food now enters the esophageal phase of the swallow (Gropher & Crary, 2020). GERD in and of itself is esophageal dysphagia. This can be characterized by regurgitation or heartburn secondary to sphincter dysfunction, diet, and lifestyle. This study will examine the presence of GERD transitioning from esophageal dysphagia to possible pharyngeal phase dysphagia.

Swallowing disorders can impact individuals across the life span and can result in concerning medical problems such as malnutrition, dehydration, aspiration pneumonia, lung disease, and choking (*Adult Dysphagia*, n.d.). In the medical setting, speech pathologists are consulted to determine swallowing safety and recommendations for an appropriate diet level for the patient. This is provided through an initial clinical swallow assessment and instrumental imaging.

The first step is to decide upon the most appropriate instrumentation for the swallowing study. The two types of instrumentation currently used by speech pathologists are modified barium swallow studies (MBSS) and a fiberoptic endoscopic evaluation of the swallow (FEES). There are pros and cons of each system depending on the goal of the examination. These tests can be used independently of each other or in addition to the other. To perform a FEES, a clinician must attend an ASHA-approved course, pass an exam following the course, complete passes of the scope on non-disordered individuals, complete passes of the scope on disordered individuals, and complete certification through the supervised mentorship (Langmore et al., 2022). However, there are no additional requirements outside of ASHA required coursework for training in performing the MBSS. It is up to the individual speech pathologist to use their clinical judgment and expertise to determine the appropriate testing.

During an MBS, the clinician introduces various consistencies of solids and liquids known as the bolus. The bolus is mixed with barium, which acts as a contrast, and is consumed by the patient under videofluoroscopy while the clinician observes swallow as it occurs (Ghazanfar et al., 2021). This also allows the clinician to identify any trials resulting in penetration or aspiration during the swallow which is when the bolus drops below the level of the vocal folds (VF) and goes into the airway; penetration occurs when the bolus drops into the laryngeal vestibule near the false vocal folds (FVF) which could result in aspiration (Stein-Rubin & Fabus, 2018). However, penetration and aspiration are not the only important pieces of information that can be gained from performing this instrumental. Additionally, the clinician observes all the phases of the swallow to determine any difficulties secondary to abnormal function of the muscles used during swallowing (Martin-Harris et al., 2000), including esophageal dysmotility. Pros of the MBSS include obtaining images of all phases of the swallow, and the ability to see aspiration/penetration during the swallow; cons include radiation exposure, the patient must come down to a specific area to complete the test, and there is no visualization of the state of the tissue (Ghazanfar et al., 2021).

For a FEES, the clinician passes a small camera in the form of a flexible endoscope through a nasal cavity until the camera reaches the hypopharynx where visualization of anatomy markers such as the epiglottis, arytenoids, and true vocal folds are present (Langmore et al., 2022). Once the camera is in place the patient will consume various consistencies of solids and liquids with food coloring added for the bolus to stand out against the tissue. Pros of this instrumental include its portability, no contrast, visualization of the state of the tissue, and no radiation; cons include the whiteout period during the swallow where the clinician is unable to see anything including aspiration during the swallow, cannot obtain visualization of the oral phase, some patients might find it uncomfortable, and the cleaning process is lengthy (Stein-Rubin & Fabus, 2018).

Although a speech pathologist can obtain a visualization of the esophageal during an MBS, their scope does not allow for treatment of these abnormalities outside of education. The importance of an interdisciplinary team cannot be understated for individuals with GERD. A gastroenterologist (GI) is referred at this point to better evaluate and understand each individual's abnormalities. This assessment often results in additional testing such as a barium swallow which assesses the esophageal motility of the liquids (Ghazanfar et al., 2021). The role of the SLP may continue if because of the GERD, there have been physiological changes in the tissue resulting in pharyngeal phase deficits. Additionally, the SLP can educate the patient on ways to manage acid reflux such as medication compliance, and eating habits, as it has been found that individuals with GERD have a significantly higher perception rate of swallowing problems than those without (Mesallam & Farahat, 2016).

In addition to this perceptual feeling of swallowing problems, individuals with GERD have a heightened risk for aspiration in several different ways. The first is regurgitation of material from the esophagus into the pharynx which can result in aspiration (Aviv et al., 2000). Of note, a threshold of 1% $(C2\text{-}4)^2$ was found to be a significant value to determine if the patient would aspirate on the subsequent swallow following residue in the pharynx (Steele et al., 2020). The second risk factor of aspiration occurs when the individual with GERD is asleep. During sleep, it has been shown that the risk of aspiration of acid reflux increases. This may be due to the reduced control the body has in repressing the flow of secretions. For example, the frequency of swallowing, and response to extraesophageal symptoms are reduced (Orr, 2003). This places the individual at high risk for aspiration. Furthermore, this prolonged exposure to stomach acids refluxing into the larynx and pharynx regions may cause damage to the surrounding tissue thus leading to impairment of vocal quality.

Dysphonia and GERD

Dysphonia occurs when there are acoustical and or physical changes that are manifested in the larynx that can affect normal vocal quality. Symptomatology of voice disorders typically includes complaints of hoarseness, tightness, difficulty producing speech, and or decrease in intelligibility when speaking (Neighbors & Song, 2022). There are two main types of voice disorders: organic and functional. Organic voice disorders are changes in structures such as the vocal folds and the areas around the vocal folds. This then causes a corresponding change in physiology resulting in perceptual abnormalities in the voice. Functional changes, however, include inappropriate use of the voice such as yelling or vocal fatigue. Dysphonia is a broad term for vocal difficulties however, different kinds of dysphonia can fall under either organic or functional disorders (American Speech and Hearing Association[ASHA], 2022).

Before conducting voice therapy, it is currently best standard practice to have the patient medically cleared by an otolaryngologist (ENT) before the patient takes part in any vigorous use of the voice under the direction of the SLP. This is to rule out anything overtly abnormal such as polyps or nodules where extraneous use may cause an exasperation of symptoms. It is here the ENT may give the patient a diagnosis of a specific dysphonia and if appropriate, refer the patient to a speech therapist for further voice evaluation and treatment. The role of the SLP includes gathering background information and screenings of respiration, phonation, resonance, and vocal range (ASHA, 2022). The initial appointment starts with the clinician completing a chart review of the patient. This would include obtaining any relevant information about the patient such as medication, history of voice or swallowing problems, past surgeries, and family history.

The next step is to ask the patient about their habits and routines. While the clinician is doing this, they will also be noting the quality of the patient's voice and obtaining subjective information. Questions would include eating and drinking habits, occupation, feelings towards their voice, etc. Every clinician/facility will complete this portion differently with their own variations of forms or procedures. With the use of subjective intake forms, the clinician would be able to quantify any progress or changes in perception from the patient during and after voice therapy. Once these are completed the clinician will move to any formal testing including acoustical measures, vibratory instruments including a Videostroboscopy, and aerodynamic measures. Common informal testing can include oral-mechanism examination, a sample of spontaneous speech, maximum phonation time, and s/z ratio (Stein-Rubin & Fabus, 2018). Not all of these measurements were previously obtained for the upcoming sample set, however, the following definitions correspond to the specific data points relevant to this study.

Acoustical measures include fundamental frequency. This is the rate of vibration of the vocal folds measured in hertz (Hz) or cycles per second. Shimmer is another vocal parameter, that measures changes in amplitude from cycle to cycle. This is quantified and measured in decibel (dB) or percentages. Harmonic-to-noise ratio (HRN) compares the level of the voice to the level of the noise outside of the voice. Jitter is a change in frequency between cycles that occur in succession measured in percentage (Merati & Bielamowicz, 2007). With the use of acoustical information, the clinician can track progress throughout therapy as well as compare the objective data points to the standardized norms for age and gender. For example, the standard fundamental frequency is approximately 100-150 Hz for males and 180-250 Hz for females. NHR, the smaller the measurement the better the voice quality of the patient this is inverted for HRN, while standard jitter is set as less than 1%, and the standard shimmer is set to be less than 0.35dB (Merati & Bielamowicz, 2007), or less than 3.8% (Teixeira & Fernandes, 2014).

The use of objective measures will enable the clinician to compare those results to current norms. The problem with this is that current norms need to also reflect the changes and evolutions of society to include all groups. Specifically, children with voice concerns, transgender individuals, people with laryngeal cancer, and other minority groups (Morris & Harmon, 2021).

Traditional therapy approaches include addressing the areas involved in phonation from both a behavioral and a functional standpoint. This would include a vocal hygiene program and specific therapy tasks related to easy onset for phonation, respiratory training, and reducing tension in the muscles used when phonating (Park et al., 2012). Like any other area within the scope of practice for a speech pathologist, it is important to conduct research to find the most up-to-date evidence-based practice. For instance, if the patient has a diagnosis with a specific dysphonia, not all techniques may be appropriate. Therapy can range in duration and frequency, and it is up to the individual clinician to recommend an interval that the patient is comfortable with. Typical therapy is 1-2 times a week for 30-60 minutes.

Due to the acidic nature of GERD, there appears to be a disruption of the vocal fold mechanism with physical and or acoustical manifestations. However, a barrier to understanding GERD's effect on voice is the reduced amount of longitudinal studies and how several decades of the diagnosis could impact the tissue of the pharynx (Bonavina et al., 2020). Furthermore, if this disease is not treated early, more profound perceptual and physical changes may occur compared to those in the early stages; as the level of exposure to the acid increases, the symptoms of GERD and established damage worsen (Sharma & Yadlapati, 2021). The use of strict medication management by the patient, and if necessary, speech and voice therapy, could perhaps halt the onset before an acceleration in symptoms.

Dysphonia has been shown to be present in patients with GERD; with speech and voice therapy, results indicate success compared to those treated with medication alone (Vashani et al., 2010). Due to the medical complexity of these patients, an interdisciplinary team is necessary to best decide how to proceed with treatment. A speech pathologist works directly with medical professionals as a consultant when speech, language, cognitive, or swallowing problems are suspected. It is the role of the individual clinician to ensure they are practicing within the scope of practice and state licensure limitations. For voice specifically, additional medical providers such as an ENT and GI are important additions to the providing team. With interdisciplinary communication and teamwork, more professionals can become aware of the scope of a speech pathologist. Education on the scope of practice is important to help others understand a speech therapist's role in the care of patients suffering from GERD. Although the problem originates in the esophagus, which is the specialty area of a GI, the reflux often reaches the level of the pharynx and larynx which then crosses over into the speech and ENT specialty.

Literature Review

A review of the literature identified the effects of acid reflux (GERD, or LPR) and the role it plays on voice or swallowing. The studies varied from the upcoming sample set in both types of equipment used and result implications. The following articles were found to be most relevant to answering the research questions outlined following the literature review. A summary of the articles is presented below.

Swallowing

Self-Perception of Swallowing-Related Problems in Laryngopharyngeal Reflux Patients Diagnosed with 24-Hour Oropharyngeal pH Monitoring (Mesallam & Farahat, 2016)

A study by Mesallam & Farahat (2016) used subjective questionnaires comparing those that have been diagnosed with GERD to a control group. Forty-four participants, with an average age of forty-four for the LPR group and forty-six for the non-LPR group, completed the questionnaires about their complaints such as the Dysphagia Handicap Index (DHI), and the Reflux Symptom Index (RSI). These participants were also monitored over twenty-four hours using a pH monitoring system where the groups were then separated into groups of those with LPR and those without. The results demonstrated there was a significant difference in swallowing difficulty perception in those with LPR when compared to those without. This study shows that individuals can appropriately identify their LPR and the presence at the very least, indicates a self-perceived swallowing problem.

Non-specific swallowing complaints, is it reflux? (Bender BK, 2007)

The findings of an article by Bender in 2007 are pertinent to the rehabilitation of an aging population. It was found that 59% of individuals 65+ have some form of reflux. The chief complaint of these patients was not heartburn, which is a traditional symptom, but a globus sensation or coughing and choking while eating. The findings of this article state that severe reflux has been found to contribute to functional changes in a patient's swallow. The reason this is such an important factor is that in the aging population there may be changes in the physiology of the tissues and muscle strength of the pharynx that, in conjunction with reflux, could cause swallowing difficulties. This is important for the medical SLP to understand because depending on the age of onset of the reflux, the damage could occur quickly and be more severe than that of the normal aging individual.

This article concludes that because of this increase in damage, meticulous evaluation and specific treatment of this population are necessary to aid in alleviating some of these symptoms. This article is important for the discussion section as to what speech-language pathologists should be looking for when working with adults who have a general complaint of swallowing problems. Bender's study focuses on swallowing and not voice. This study used a videofluoroscopy also known as a modified barium swallow study (MBSS) rather than the FEES. This is important because if the etiology of the swallowing problem is related to GERD, a modified barium swallow study would not be appropriate. An MBS would appear normal when the patient is complaining of a globus sensation. There would also not be a way to see the damage that may have been done from the acid reflux.

Laryngopharyngeal Sensory Deficits in Patients with Laryngopharyngeal Reflux and Dysphagia (Aviv et al., 2000)

A study by Aviv et al (2000) used a FEES to assess the sensory function and the state of the pharynx in individuals diagnosed with dysphagia and a control group. Of the fifty-four patients with dysphagia, 70% were found to have LPR. The study aimed to determine if there was a significant difference in sensory function of individuals without LPR compared to those diagnosed with LPR. This was accomplished by sending air pulses while the endoscope was in place to identify whether or not the muscles of the larynx would adduct as a reflex in response to the stimulus. The sensory function of the larynx is extremely important for airway protection. In addition to the sensory function, this study also obtained visual information on the state of the pharynx with the presence of LPR.

It was concluded that with individuals with dysphagia, 89% of patients had edema in the larynx, and 78% were noted to have laryngopharyngeal sensory deficits. Another important data point taken away from this study was of the thirty-eight individuals with LPR, 51% were found to have severe sensory deficits. This severe group was broken down even further where it was found that 88% Of these eighteen participants in the severe deficits category, sixteen penetrated during the study, while nine aspirated. After a three-month treatment period using a PPI, twenty-three participants returned, twelve of whom had severe sensory deficits. After treatment, the number of severe sensory deficits reduced from twelve to three. The article concluded that laryngopharyngeal edema often results in reduced sensory deficits in those with LPR. Treatment of a PPI shows significant improvement in both the edema and the sensory function of the larynx.

This is important because patients with acid reflux are at a heightened risk of aspiration due to regurgitation. This study found that those with reflux have reduced sensory function which was shown to also have a higher prevalence of aspiration compared to those with no sensory deficits. This study did not obtain any acoustical information on the voice of the patients with LPR.

Voice

Acoustic Analysis Findings in Objective Laryngopharyngeal Reflux Patients (Oguz et al., 2007)

A study by Oguz et al. (2007) examined acoustic information for those with objective LPR, symptomatic LPR, and control subjects. It was found that frequency perturbation measures were higher in both LPR groups compared to the control group. However, most measures were not found to be statistically significant between the LPR groups. The only measure found to be statistically different was the mean noise-to-harmonics ratio when compared to both the symptomatic LPR participants and the control group. LPR groups had lower fundamental frequencies compared to the control group but not between the two groups. Additionally, the descriptive information of the laryngeal structures in those with LPR included edema and thick or excessive endolaryngeal mucus. This article also stated that an MBSS usually does not show abnormalities in this population. The article concludes by stating the importance of objective measurements such as acoustic values. Using numerical and objective data, advancements in the treatment of voice disorders are possible. The article also states that understanding these measurements may contribute positively to the compliance of the patient which would likely increase a patient's quality of life. Finally, understanding acoustical measures and increasing patient compliance should also increase motivation from a physician. This is because medical therapy is typically long-term in the treatment of LPR.

Gastroesophageal Reflux Disorder: Lifestyle, Symptomatology, and Voice Profile (Ganesan et al., 2017)

A comprehensive study by Ganesan et al. (2017) on adults (40+) compared individuals with and without GERD. This study found that of their participants, 70% had diets that would impact their disease, and 94% had high-stress, sedentary lifestyles. The article demonstrated the behavioral aspect related to GERD. Through the use of questionnaires that gave detailed background on the participants, it was found a higher prevalence of LPR was correlated to specific lifestyles. These participants demonstrated symptoms such as dry cough, voice changes, and general irritation or pain in the throat. Visualization of the pharynx was completed by a rigid endoscope and results noted in the clinically diagnosed group included a cobblestone appearance, which are small bumps of tissue of the posterior pharyngeal wall, edema of the arytenoids, arytenoid congestion, and vocal cord congestion as noted by thickened secretions which can lead to decreasing the maneuverability of the vocal folds. Finally, acoustic measurements also found a significant difference between the two groups in frequency and perturbation.

Perceptual aerodynamic and acoustic characteristics of voice changes in patients with laryngopharyngeal reflux disease (Lechien et al., 2019)

A study completed by Lechien et al. (2019) had eighty participants who had been identified to have LPR through various reflux index rating systems. This group was compared to eighty participants who were identified as not having LPR using subjective and objective data points. Not only did this study find a significant difference in frequency and perturbation as Ganesan et al., but they also found differences in voice quality such as strain, breathiness, and roughness. Additionally, there were significant differences in jitter, shimmer, the standard deviation of the fundamental frequency, and noise to harmonic ratio. This study also investigated parameters not assessed in this sample set and found significant differences in peak-to-peak amplitude and specific information utilizing the Voice Handicap Index. One key point from this study is that they did not find a significant correlation between vocal fold edema and the objective voice measurements that were taken. This is consistent with the Aviv et al. study that found more edema in the tissue surrounding the vocal folds and not just the vocal folds. The authors conclude that individuals with LPR show significant change or adverse symptoms with both subjective and objective measurements compared to those without.

This current study aims to assess the influence of GERD as a predictor of voice disorders. A barrier to this is the lack of longitudinal studies showing the effects of GERD and how several decades of the diagnosis could impact the tissue of the pharynx (Bonavina et al., 2020). None of the studies reviewed above utilize the use of combined instrumentation of the videostrobe, Visi-Pitch, and FEES to obtain measures linking GERD as a predictor of voice abnormalities and swallowing deficits. This is the gap that this current study aims to fill. Based on the result of the literature review, three research questions emerged.

Research Questions and Hypothesis

(1) Is there a visible tissue change in the pharynx related to GERD? (2) Are there any corresponding acoustic abnormalities (F0, shimmer, and jitter) in the presence of GERD? (3) Are there any associated swallowing difficulties? The corresponding hypotheses for these research questions 1: It is hypothesized that tissue changes in the pharynx may be related to the presence of GERD. 2: It was further hypothesized that because of the diminished function of the vocal folds, there may be changes in acoustic parameters in individuals with the presence of GERD, particularly with individuals who have been managing their diagnosis for a longer period. 3: A final hypothesis was due to the acidic nature of reflux, there may be abnormalities noted on the FEES in the presence of GERD. This research is becoming more relevant due to the role speech-language pathologists play in managing both voice and swallowing disorders in patients.

CHAPTER II

METHODS

This study was retrospective as all data had been collected in the principal investigator's speech and swallowing lab at Cleveland State University. This research was approved by the Cleveland State University Institutional Review Board. All individuals signed a consent form before completing any instrumental evaluations. This stated the results of the evaluation and basic information such as gender, age, and general medical history may be used in future research studies. No identifying information about the individuals was revealed. This study analyzed the influence of GERD on voice and swallowing. The co-investigator was blinded to past medical history during the analysis of the data. After the analysis was completed, the co-investigator was unblinded to the past medical history, including whether the participants had a medical diagnosis of GERD and if they were currently treating it with medication. This enabled the co-investigator to remain objective through the analysis and only describe what was seen with the raw data.

Participants

For this study, there were eight female and four male participants. The participants ranged from age 20-52 (M=26; SD=10.6) The retrospective studies were selected based on some participants' history of GERD. A normal group of participants

Table 1: *Demographic Information of Participants*

Participant	Age	Gender	Diagnosis/PMH	Treatment	Other
1	21	Female	GERD	Medication	N/A
2	23	Male	GERD Complains of swallowing problems	Anti-acid medication as needed	C1 laminectomy and dura plasty
3	21	Female	Denied diagnosis	N/A	N/A
4	21	Female	Denied diagnosis	N/A	N/A
5	21	Female	GERD	Anti-acid medication as needed	N/A
6	45	Female	GERD Complaints of vocal strain and pain	Medication	History of thyroid surgery Teacher
7	22	Male	Denied diagnosis	N/A	N/A
8	21	Female	Denied diagnosis	N/A	N/A
9	52	Male	GERD 10+ years Complaints of vocal strain	Medication Previously seen SLP	Public speaker
10	22	Female	Denied diagnosis	N/A	N/A
11	21	Male	Denied diagnosis	N/A	N/A
12	23	Female	GERD	Medication	N/A

that did not have a medical diagnosis of GERD was included as a control group. Because of this, there was a decreased level of control with the types of participants included. This includes not having all data points for every individual. **Table 1** depicts the demographic information of the participants and what data was collected for each. The data that had been previously collected was completed without a specific research study in mind. Thus, every evaluation may have been completed with slight variations and reduced control from the authors.

Procedure

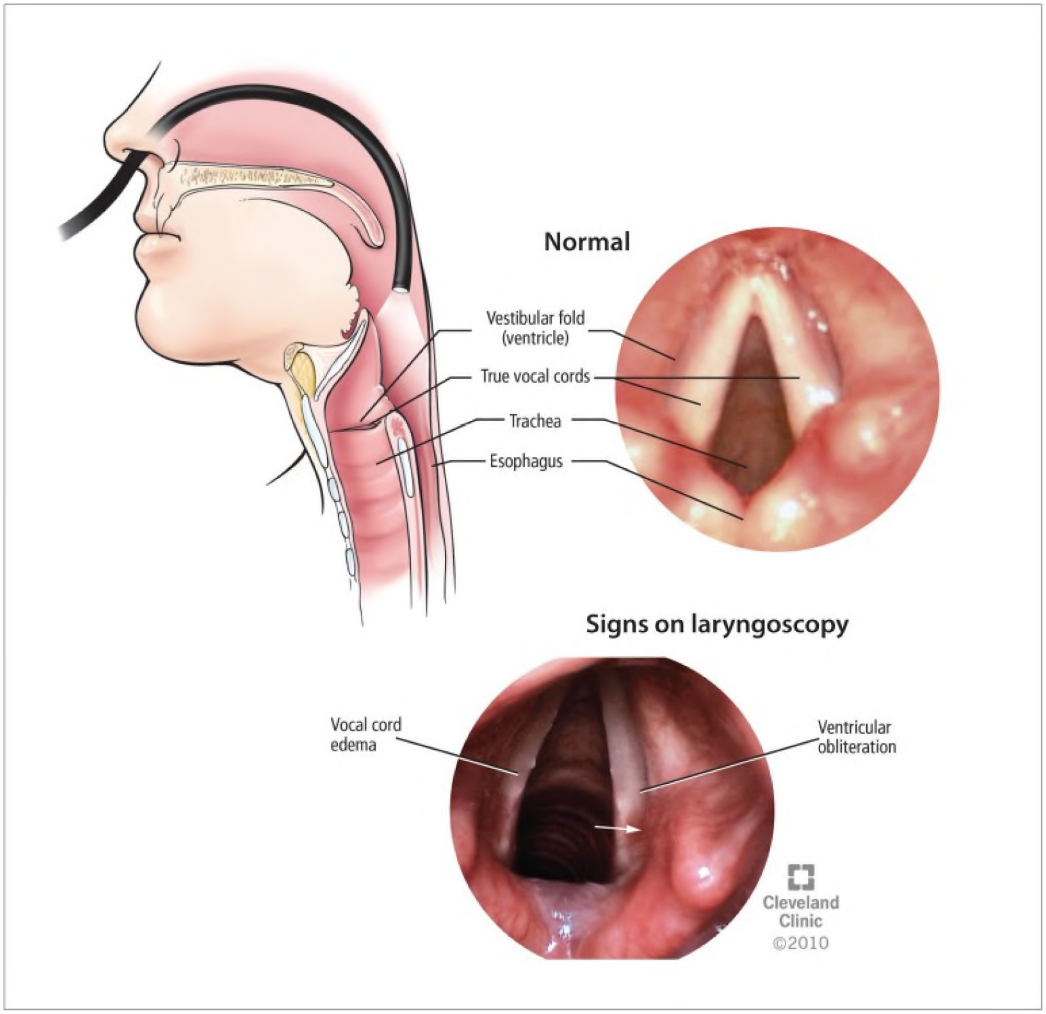
Three sets of data were previously collected for each participant via Visi-Pitch, Videostroboscopy, and the fiberoptic endoscopic evaluation of the swallow (FEES). The acoustic information was collected via KayPentax Visi-Pitch IV, Model 3950B. Videostroboscopic information was previously collected via KayPentax Model 9106 Endoscope connected to a KayPentax Model 9400 Laryngeal Strobe and a Panasonic 3 CCD HD Camera Head. This was also connected to a KayPentax Video Processor EPK-i5010. For the FEES, a KayPentax Digital Swallowing Workstation Model 7200C was utilized.

The participant's prior medical information was obtained from the notes of the primary investigator. This included the participants' perception of their vocal quality information, swallowing history, and length of time of existing voice and swallowing problems. Data from the Visi-Pitch were analyzed based on the participants' prior production of the vowel sounds /i/ and /a/. Acoustic parameters such as fundamental frequency, shimmer, jitter, and noise-to-harmonic ratios (NHR) were obtained from the recordings that were stored on the hard drive of the Visi-Pitch system.

The second step was to inspect the appearance of the vocal fold images from video recordings as stored on the Videostroboscopic system. The co-investigator diligently reviewed the following areas of the larynx from Videostroboscopic recordings: laryngeal area, vocal fold mucosa. With this program, an evaluator can utilize various settings that can record and manipulate numerical information from the mucosal wave. However, those settings were not used for this study as this research study was not in mind at the time of collection.

The third step was to view the recordings of the FEES imaging taken for the participants. In this case, the co-investigator observed aspects of the participants' swallowing patterns to verify any changes in the physiology of the swallow that might be correlated with anatomic changes seen via Videostroboscopy. The FEES observation was classified as either normal or abnormal. For this type of study, the scope was passed through the nasal cavity to the larynx where it was situated during the evaluation. This pathway is shown in **Figure 1**. Once the camera was in place, most of the participants were given to eat (cracker) and to drink (water). The swallow participants were only observed during a volitional swallow.

Figure 1: *Pathway of the Endoscope During FEES*



Method of Analysis

Data were extrapolated by the PI's research assistant who assigned a number to each. The newly named data were transferred to an external hard drive and given to the co-investigator for analysis.

A list was created by the research assistant that recorded the participant number and demographic information which included gender, age, and relevant past medical history. This list was not shared with the co-investigator until the analysis was completed. This was to ensure no bias of information including whether the patient had a diagnosis of GERD or was currently taking medication related to managing their GERD.

Specific information stored on the external hard drive was (1) output related to acoustical information in the form of a chart and list of raw data, (2) the video recording of the vocal fold examination completed via Videostroboscopy, and (3) the video recording of the swallowing evaluation completed via FEES.

CHAPTER III

RESULTS

Each participant's raw data, including still images from either the videostrobe or FEES as well as data related to acoustical measures, can be found under the corresponding participant number. Under the images and charts is a summarization of descriptive statistics noted by the co-investigator during the analysis. A summary of the results from the videostrobe examination such as mucosal wave identification, vocal fold appearance and function, and surrounding tissue appearance is presented in tables and pictures. This includes descriptive information from the FEES such as swallow onset, presence of penetration or aspiration before or after the swallow, residue, and appearance of tissue. In addition to the data from the video recordings, the acoustical information charts also display the norms for each area, for example, gender norms for males (M) and females (F), and for NHR.

Participant 1

Table 2: *Visi-Pitch Acoustic Values for Participant 1*

Acoustical Information	Value	Norms
Fundamental Frequency	221Hz	M:100-150Hz F: 180-250Hz
Shimmer	2.36%	<3.8%
Jitter	0.637%	<1%
Noise-to-Harmonic Ratio	0.083 NHR	Low

Table 2 depicts the acoustical information gathered from the Visi-Pitch for participant 1. **Figure 2** shows the measurements within normal limits below as all values are within the green circle.

Figure 2: *Visi-Pitch Acoustic Output for Participant 1*

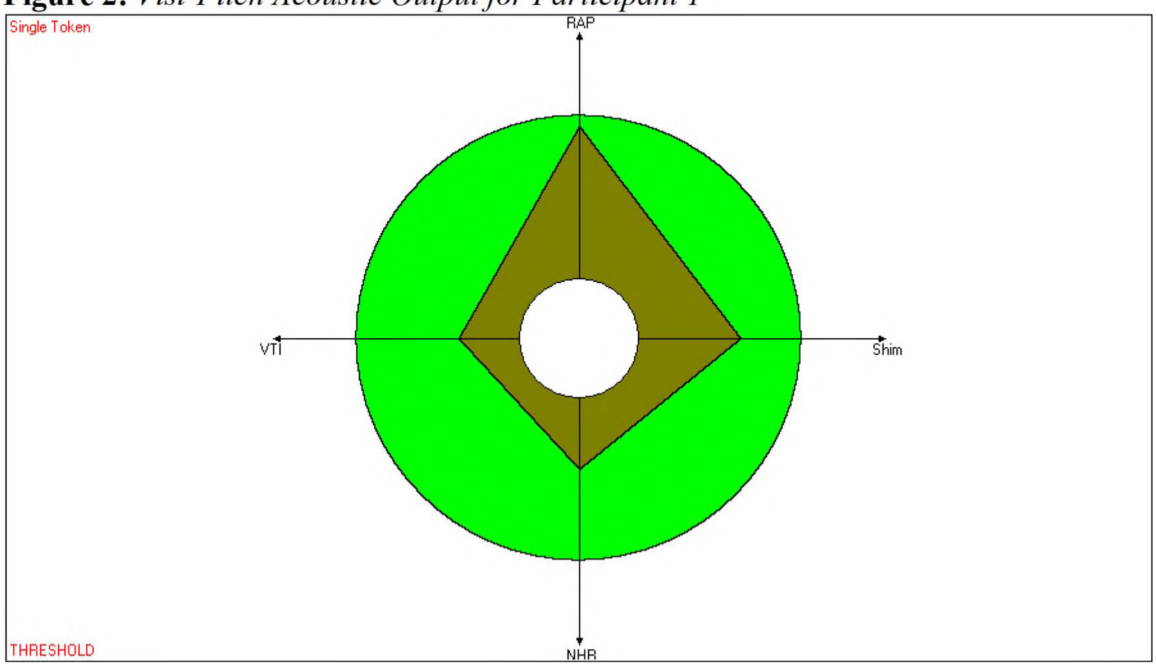


Figure 3a: *Videostroboscopic Imaging of VF in Adducted Position*

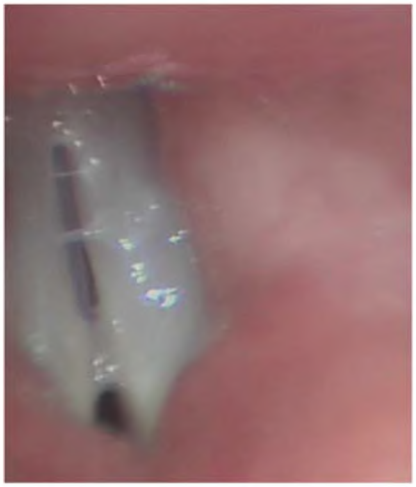


Figure 3b: *Videostroboscopic Imaging of VF in Abducted Position*

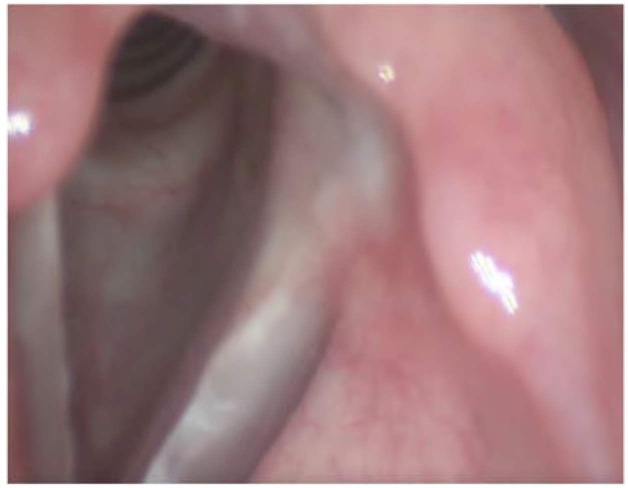


Table 3: *Videostroboscopic Descriptive Information for Participant 1*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
1	Present	White Noted thickened moderate secretions **(Figure 3a)** Left VF appears thicker than the right (**Figure 3a)** Slight edema noted on the anterior portion of the false vocal folds Slight fissure on the left VF in **Figure 3b**	Symmetrical arytenoid movement Appropriate distance between VF during adduction	Vascular with redness present in **Figure 3a** and **Figure 3b** All anatomy present with an omega-shaped epiglottis

Figure 4a: *FEES Imaging of the Pharyngeal Space for Participant 1*

Figure 4b: *FEES Imaging After the Swallow of a Bolus for Participant 1*

Table 4: *FEES Descriptive Information for Participant 1*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
1	Timely with slight premature spillage of initial bolus to the vallecula	Deep penetration to the false vocal folds was observed cleared with additional swallow Mild residue (**Figure 4b)** on tongue base, left pyriform sinus, and pharyngeal wall cleared on subsequent swallow	Moderate to severe cobblestone appearance shown by **Figure 4a**	Vascular with redness Moderate cobblestone appearance on the tongue base shown by **Figure 4a** All anatomy present with omega-shaped epiglottis

Participant 2

Table 5: *Visi-Pitch Acoustic Values for Participant 2*

Acoustical Information	Value	Norms
Fundamental Frequency	171.161 Hz	M:100-150Hz F: 180-250Hz
Shimmer	3.639%	<3.8%
Jitter	0.202%	<1%
Noise-to-Harmonic Ratio	0.115 NHR	Low

Table 5 depicts the acoustical information gathered from the Visi Pitch for participant 2. **Figure 5** shows the measurements within normal limits below as all values are within the green circle.

Figure 5: *Visi-Pitch Acoustic Output for Participant 2*

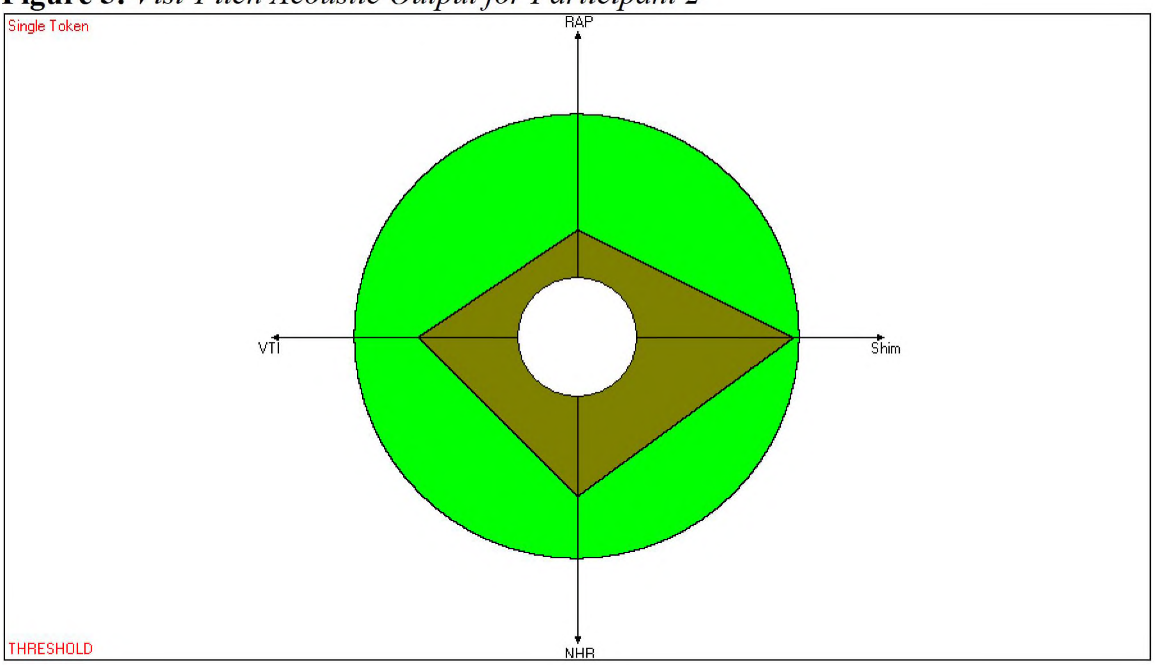


Figure 6a: *Videostroboscopic Imaging of the VF in the Adduction Position*

Figure 6b: *Videostroboscopic Imaging of the VF in the Adduction Position*

Table 6: *Videostroboscopic Descriptive Information for Participant 2*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
2	Present	White with noted redness of the left vocal fold most notable in **Figure 6a** distally with mild secretions Edema of the false vocal folds shown in **Figure 6b**	Symmetrical movement of arytenoids with noted intact adduction	Moderate to severe vascular tissue with noted redness

Figure 7a: *FEES Imaging of the Pharyngeal Space for Participant 2*

Figure 7b: *FEES Imaging After the Swallow of a Bolus for Participant 2*

Table 7: *FEES Descriptive Information for Participant 2*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
2	Timely	Moderate residue on tongue base from bolus (cracker) (**Figure 7b**) more significant residue on left side that did not clear with an additional swallow or a liquid wash	Mild cobblestone appearance	Vascular with redness All anatomy present with reduced distance from epiglottis to tongue base shown in **Figure 7a** Moderate cobblestone appearance of tongue base

Participant 3

Table 8: *Visi-Pitch Acoustic Values for Participant 3*

Acoustical Information	Value	Norms
Fundamental Frequency	246.870 Hz	M:100-150Hz F: 180-250Hz
Shimmer	1.465%	<3.8%
Jitter	0.131%	<1%
Noise-to-Harmonic Ratio	0.130 NHR	Low

Table 8 depicts the acoustical information gather from the Visi Pitch for participant 3. This participant also had a slightly elevated peak-to-peak amplitude variation shown in **Figure 8** shows the measurements within normal limits below as all values are within the green circle.

Figure 8: *Visi-Pitch Acoustic Output for Participant 3*

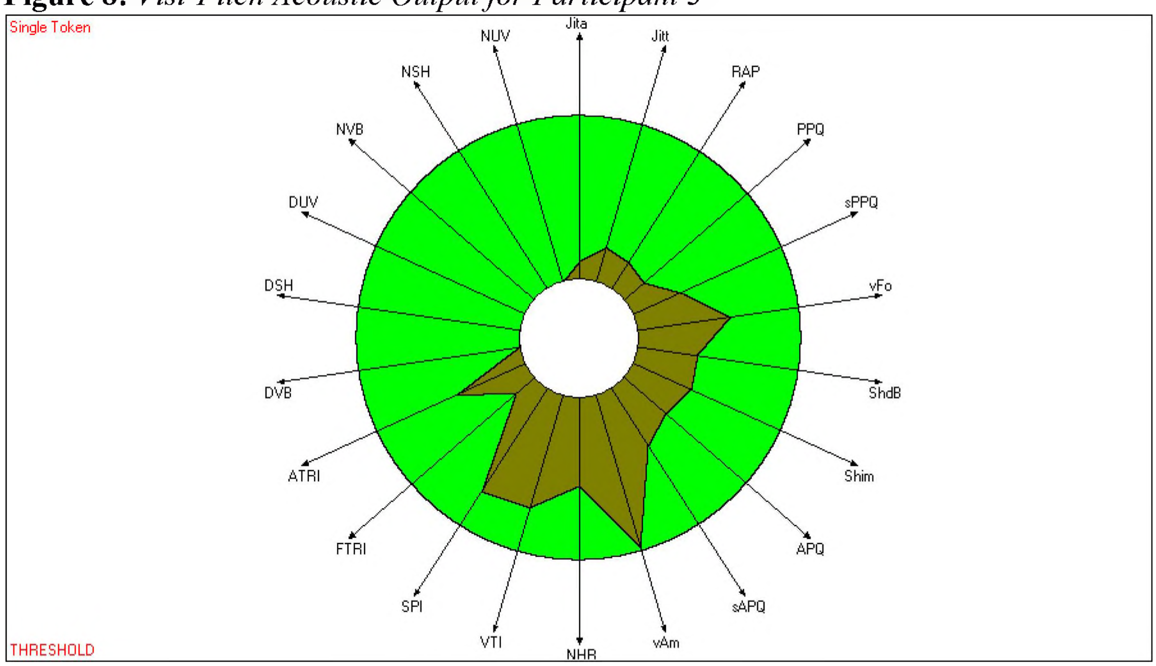


Figure 9a: *Videostroboscopic Imaging of the VF in the Abducted Position*

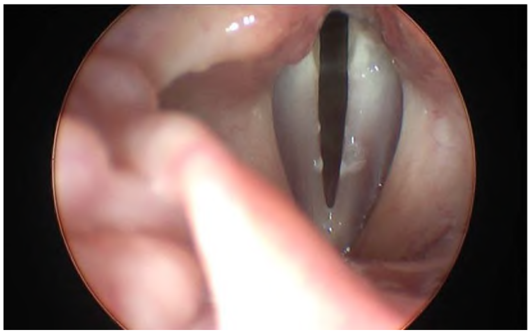


Figure 9b: *Videostroboscopic Imaging of the VF in the Adducted Position*

Table 9: *Videostroboscopic Descriptive Information for Participant 3*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
3	Present	White Mild secretions were noted on the VF shown in **Figure 9a**	VF move independently and are symmetrical during opening/closure	False VF has trace to mild vascularity and redness Right side of the tongue base showed mild cobblestoning shown **Figure 9a** and **Figure 9b**

Figure 10a: *FEES Imaging of the Pharyngeal Space for Participant 3*

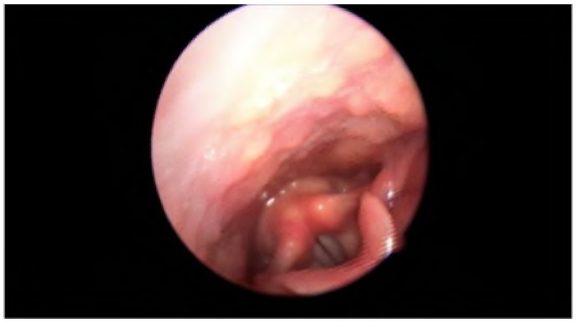


Figure 10b: *FEES Imaging of the Pharyngeal Space for Participant 3*

Table 10: *FEES Descriptive Information for Participant 3*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
3	Timely for consecutive sips of liquid	None observed	Mild to moderate cobblestone appearance shown in **Figure 10b**	Mild cobblestone appearance of the tongue base (**Figure 10b**) Mild edema of the arytenoids characterized by redness (**Figure 10a**)

Participant 4

Table 11: *Visi-Pitch Acoustic Values for Participant 4*

Acoustical Information	Value	Norms
Fundamental Frequency	200Hz	M:100-150Hz F: 180-250Hz
Shimmer	3.556%	<3.8%
Jitter	0.877%	<1%
Noise-to-Harmonic Ratio	0.114 NHR	Low

Table 11 depicts the acoustical information gather from the Visi Pitch for participant 4. This participant had a greater peak-to-peak amplitude variation as shown in **Figure 11** which identifies the elevated measurements marked in red.

Figure 11: *Visi-Pitch Acoustic Output for Participant 4*

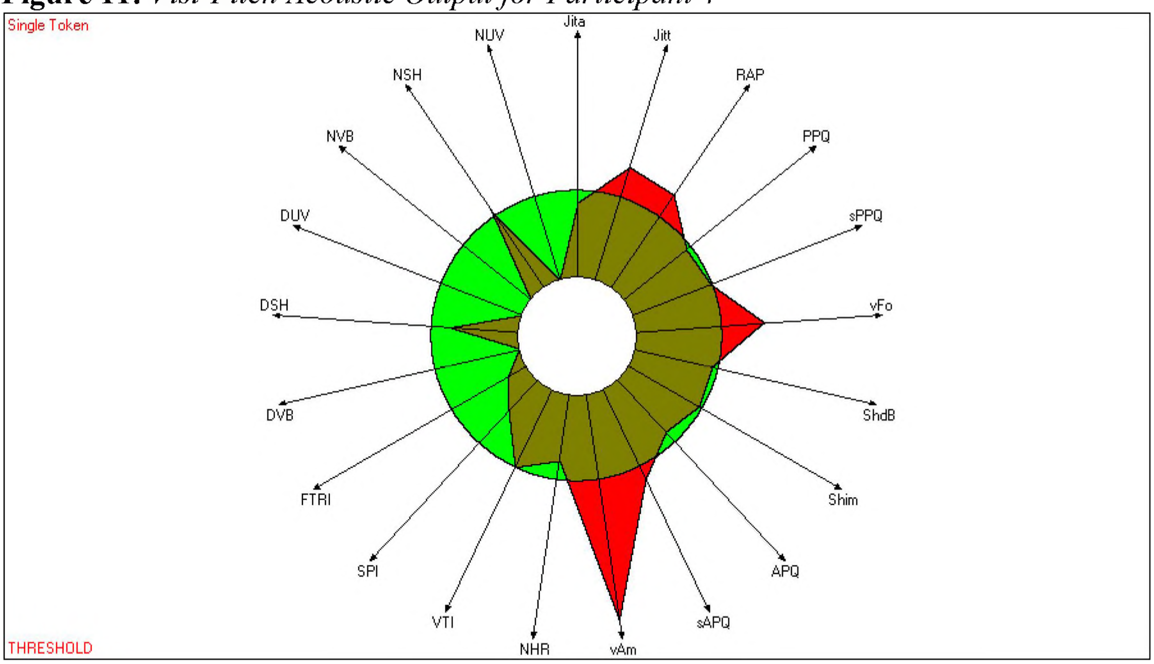


Figure 12a: *Videostroboscopic Imaging of the VF in the Abducted Position*

Figure 12b: *Videostroboscopic Imaging of the VF in the Adducted Position*

Table 12: *Videostroboscopic Descriptive Information for Participant 4*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
4	Present	White Right VF appeared slightly thickened distally (**Figure 12a**) VF appear short in length	Appropriate movement of arytenoids with the left moving slightly faster to the midline Mild to moderate edema of the arytenoids (**Figure 12b**)	Tissue appears red and slightly enflamed posteriorly (**Figure 12b**) Moderate vascular appearance of tissue, specifically the epiglottis (**Figure 12a**) Mild to moderate cobblestone appearance of tongue base Epiglottis shape characterized by exaggerated curl anteriorly toward tongue base

Participant 5

Table 13: *A Visi-Pitch Acoustic Values for Participant 5*

Acoustical Information	Value	Norms
Fundamental Frequency	243.863 Hz	M:100-150Hz F: 180-250Hz
Shimmer	3.482%	<3.8%
Jitter	0.639%	<1%
Noise-to-Harmonic Ratio	0.089	Low

Table 13 depicts the acoustical information gather from the Visi Pitch for participant 5. This participant has slightly elevated measurements in shimmer and jitter, **Figure 13** shows the measurements within normal limits below as all values are within the green circle.

Figure 13: *Visi-Pitch Acoustic Output for Participant 5*

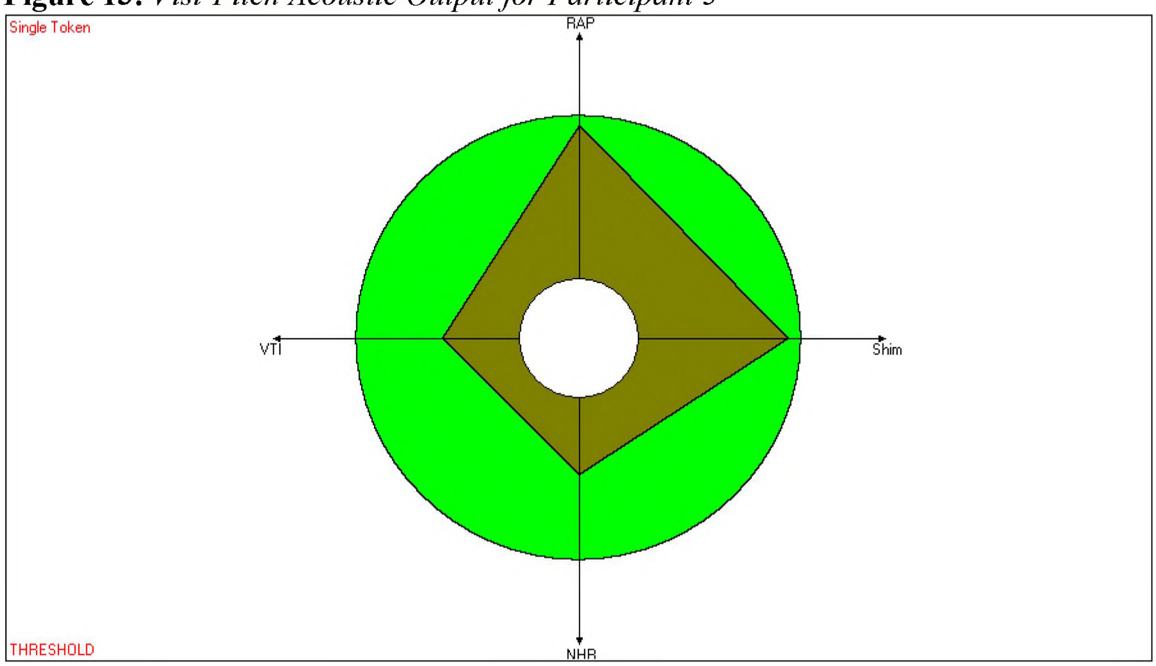


Figure 14a: *Videostroboscopic Imaging of the VF in the Abducted Position*

Figure 14b: *Videostroboscopic Imaging of the VF in the Adducted Position*

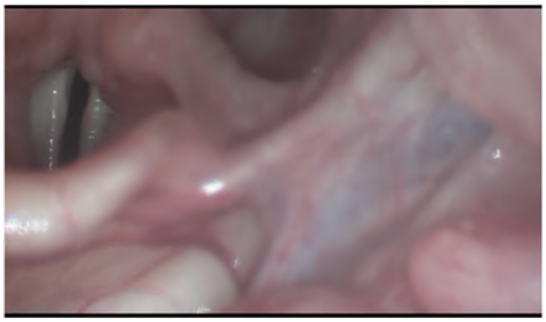


Table 14: *Videostroboscopic Descriptive Information for Participant 5*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
5	Present	White Right VF appears slightly thickened compared to left (**Figure 14a**) VF appear short in length	Symmetrical movement of the arytenoids Reduced movement of the left VF medially compared to the right	Mild to moderate vascularity (**Figure 14b**) Epiglottis shape was unremarkable

Figure 15a: *FEES Imaging of the Pharyngeal Space for Participant 5*

Figure 15b: *FEES Imaging of the Pharyngeal Space for Participant 5*

Table 15: *FEES Descriptive Information for Participant 5*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
5	Although no bolus was introduced, swallow appeared timely for volitional swallow of secretions	None observed	Trace to mild cobblestone appearance (**Figure 15a**)	Mild to moderate vascularity of the tongue base (**Figure 15b**)

Participant 6

Table 16: *Visi-Pitch Acoustic Values for Participant 6*

Acoustical Information	Value	Norms
Fundamental Frequency	196.645Hz	M:100-150Hz F: 180-250Hz
Shimmer	1.95%	<3.8%
Jitter	0.804%	<1%
Noise-to-Harmonic Ratio	0.126 NHR	Low

Table 16 depicts the acoustical information gather from the Visi Pitch for participant 6. This participant had a heightened measure in jitter. **Figure 16** below depicts the acoustical information which identifies the elevated measurements marked in red.

Figure 16: *Visi-Pitch Acoustic Output for Participant 6*

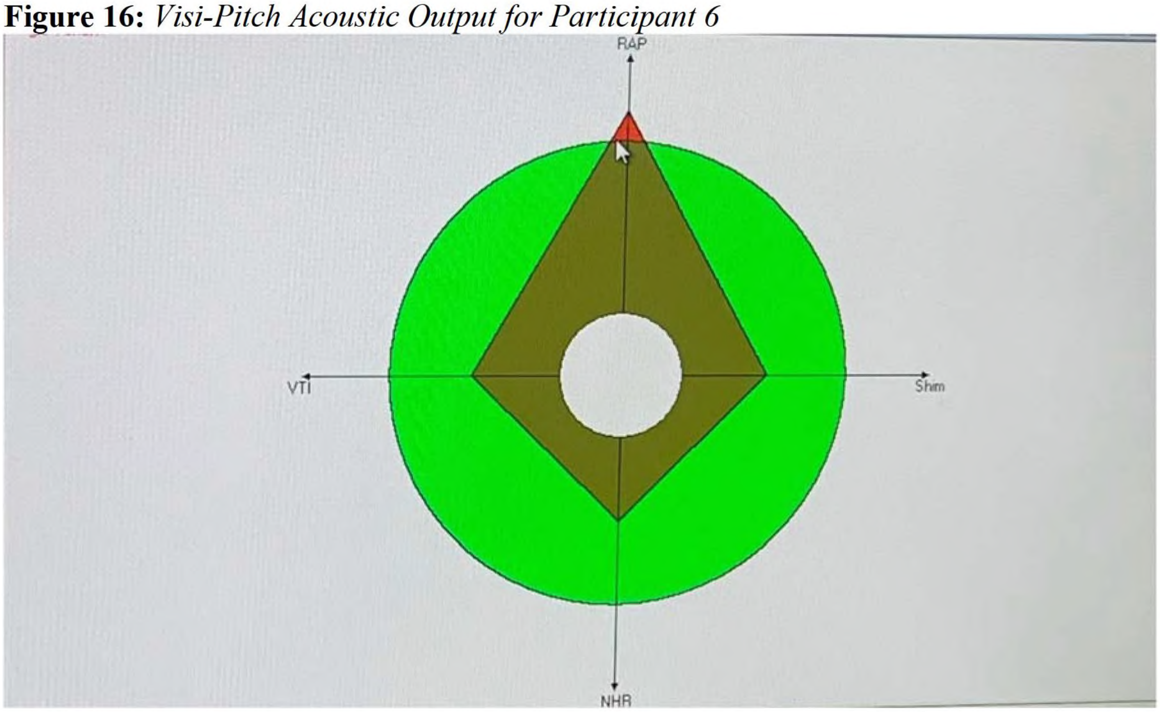


Figure17a: *Videostroboscopic Imaging of the VF in the Abducted Position*

Figure 17b: *Videostroboscopic Imaging of the VF in the Adducted Position*

Table 17: *Videostroboscopic Descriptive Information for Participant 6*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
6	Present	Mostly white with noted vascularity of the left and right VF (**Figure 17a)** Thickening of the posterior portion of the left VF Moderately thickened secretions anteriorly (**Figure 17b**)	Reduced movement of the posterior portion of the right VF medially Left VF movement slightly faster than the right	Tissue appears red and slightly inflamed (**Figure 17a**) Noted moderate vascularity within the false VF (**Figure 17a**) Edema of the anterior portions of the false FV (**Figure 17b**)

Participant 7

Table 18: *Visi-Pitch Acoustic Values for Participant 7*

Acoustical Information	Value	Norms
Fundamental Frequency	138.036 Hz	M:100-150Hz F: 180-250Hz
Shimmer	2.44%	<3.8%
Jitter	0.486%	<1%
Noise-to-Harmonic Ratio	0.132 NHR	Low

Table 18 depicts the acoustical information gather from the Visi Pitch for participant 7. **Figure 18** shows the measurements within normal limits below as all values are within the green circle.

Figure 18: *Visi-Pitch Acoustic Output for Participant 7*

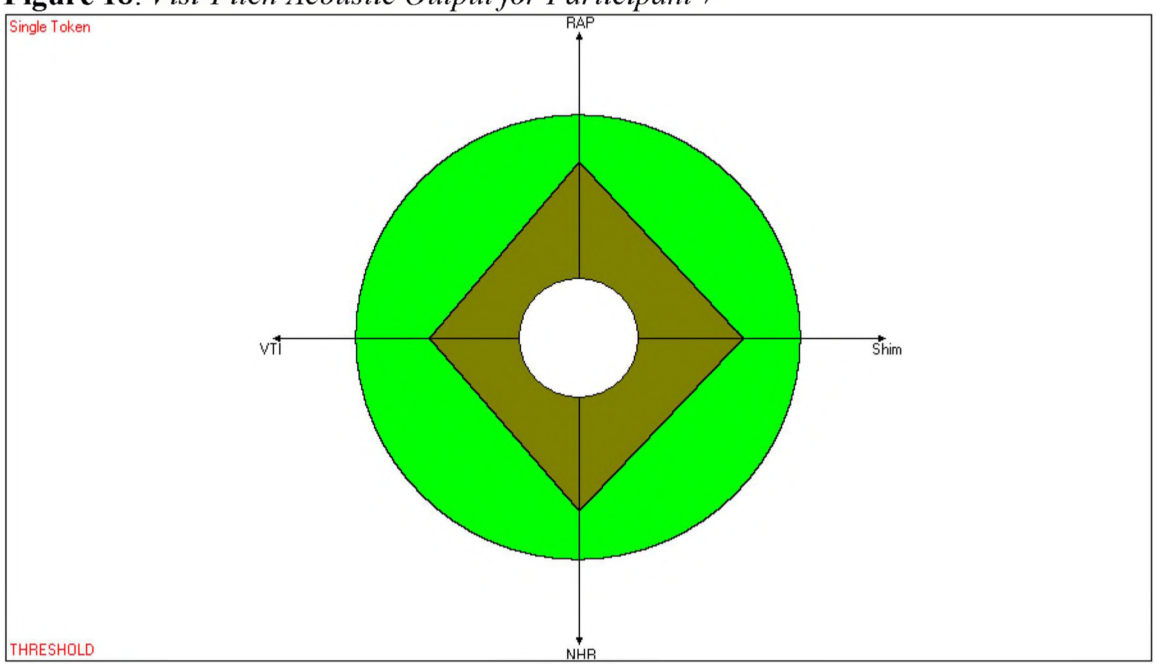


Figure 19a: *Videostroboscopic Imaging of the VF in the Adducted Position*

Figure 19b: *Videostroboscopic Imaging of the VF in the Abducted Position*

Table 19: *Videostroboscopic Descriptive Information for Participant 7*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
7	Present	White	Symmetrical movement of the arytenoids Almost complete adduction with even movement	False VF show trace vascularity (**Figure 19b**) All anatomy present and unremarkable

Figure 20a: *FEES Imaging of the Pharyngeal Space for Participant 7*

Figure 20b: *FEES Imaging of the Pharyngeal Space for Participant 7*

Table 20: *FEES Descriptive Information for Participant 7*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
7	Although no bolus was introduced, swallow appeared timely for volitional swallow of secretions	None observed	Intact	Trace-mild cobble stone appearance of the tongue base with omega-shaped epiglottis (**Figure 20b**)

Participant 8

For participant 8 the raw data extrapolated from the chart was not able to be collected. Measurements of shimmer and jitter appear to be within normal limits as shown in **Figure 21** below. Of note, this participant had an elevated measure of peak-to-peak amplitude variation and a slightly elevated NHR.

Figure 21: *Visi-Pitch Acoustic Output for Participant 8*

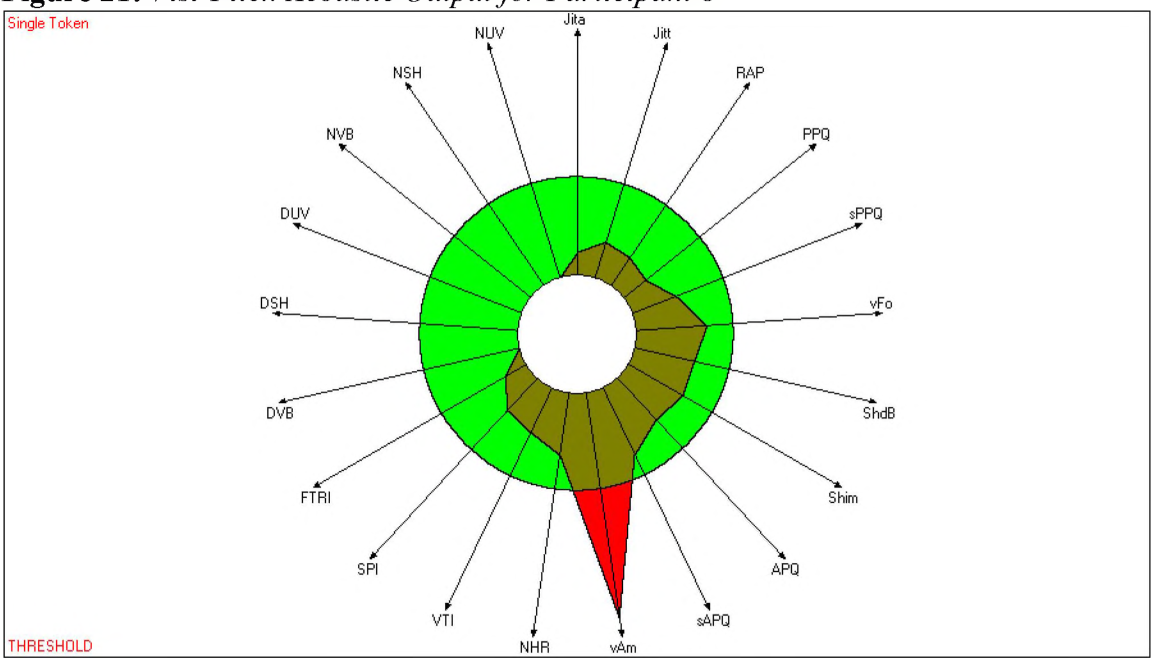


Figure 22a: *Videostroboscopic Imaging of the VF in the Adducted Position*

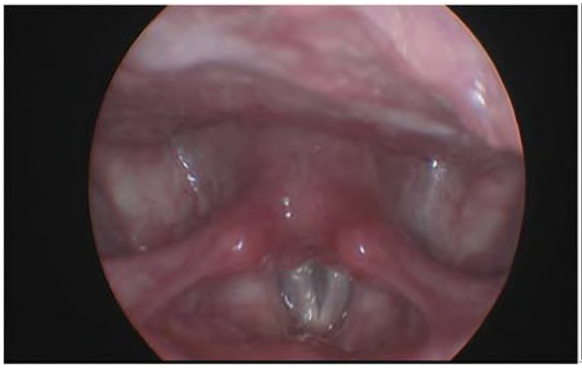


Figure 22b: *Videostroboscopic Imaging of the VF in the Abducted Position*

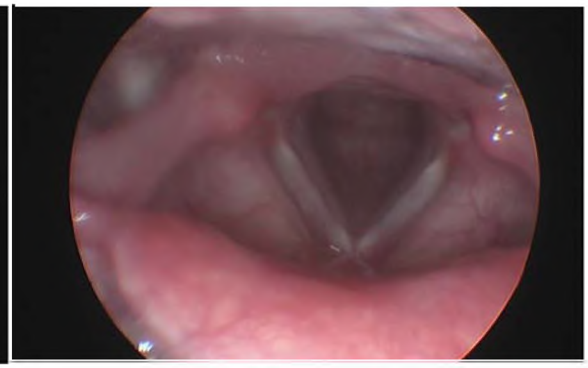


Table 21: *Videostroboscopic Descriptive Information for Participant 8*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
8	Present	White with moderate vascularity resulting in uneven coloration (**Figure 22b**) VFs appear short with reduced symmetry medially (**Figure 22a**)	Symmetrical movement of the arytenoids Symmetrical medially movement of the VF for adduction	Moderate vascularity in the pyriform sinus and area around the false VF (**Figure 22b**) Edema of the arytenoids (**Figure 22a)** Noted vascularity on the underside of the epiglottis (**Figure 22b)**

Participant 9

Table 22: *Visi-Pitch Acoustic Values for Participant 9*

Acoustical Information	Value	Norms
Fundamental Frequency	147.813	M:100-150Hz F: 180-250Hz
Shimmer	9.411%	<3.8%
Jitter	1.996%	<1%
Noise-to-Harmonic Ratio	0.407 NHR	Low

Table 22 depicts the acoustical information gathered from the Visi Pitch for participant 9, This participant has elevated measures of shimmer. This participant also has a higher measurement in NHR as well shown in **Figure X** which identifies the elevated measurements marked in red.

Figure 23: *Visi-Pitch Acoustic Output for Participant 9*

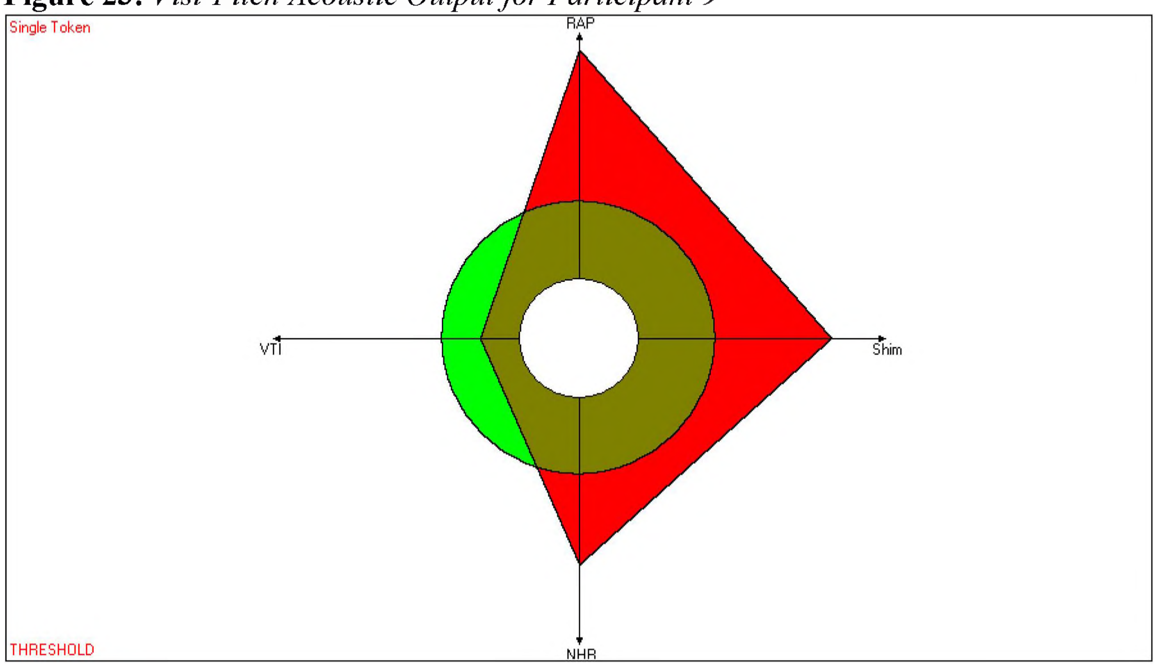


Figure 24a: *Videostroboscopic Imaging Posterior Pharyngeal Vestibule*

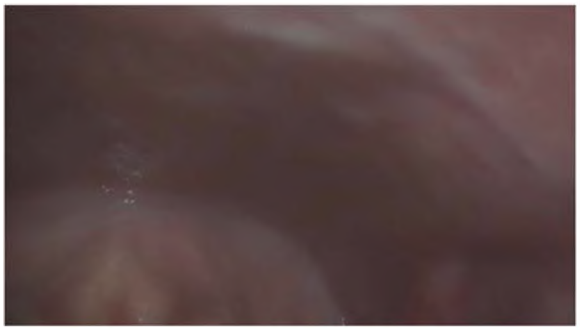


Figure 24b: *Videostroboscopic Imaging of the Arytenoids in the Adducted Position*

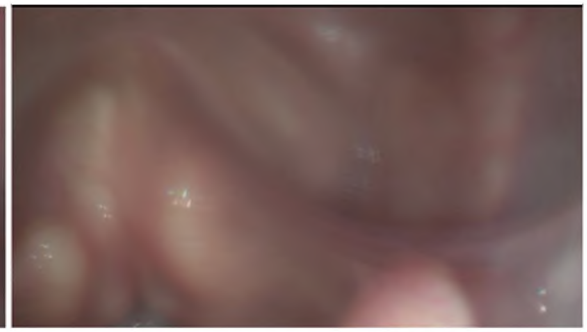


Table 23: *Videostroboscopic Descriptive Information for Participant 9*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
9	Present	Not observed due to the participant's gag reflex	Not observed due to the participant's gag reflex Noted tightness seen through jerky movements of the arytenoids	Mild to moderate edema noted in the pyriform sinus and arytenoids (**Figure 24b**) Moderate vascularity (**Figure 24b**)

Figure 25a: *FEES Imaging of the Pharyngeal Space for Participant 9*

Figure 25b: *FEES Imaging of the Tongue Base for Participant 9*

Table 24: *FEES Descriptive Information for Participant 9*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
9	Timely swallow of cracker	Trace residue of cracker on tongue base after the swallow, cleared with additional swallow (**Figure 25b**)	Mild to moderate cobble stone appearance (**Figure 25a**)	Noted moderate discoloration of the tongue base (**Figure 25b**)

Participant 10

Table 25: *Visi-Pitch Acoustic Values for Participant 10*

Acoustical Information	Value	Norms
Fundamental Frequency	245.100Hz	M:100-150Hz F: 180-250Hz
Shimmer	2.839%	<3.8%
Jitter	0.350%	<1%
Noise-to-Harmonic Ratio	0.112 NHR	Low

Table 25 depicts the acoustical information gather from the Visi Pitch for participant 7**. Figure 26** shows the measurements within normal limits below as all values are within the green circle.

Figure 26: *Visi-Pitch Acoustic Output for Participant 10*

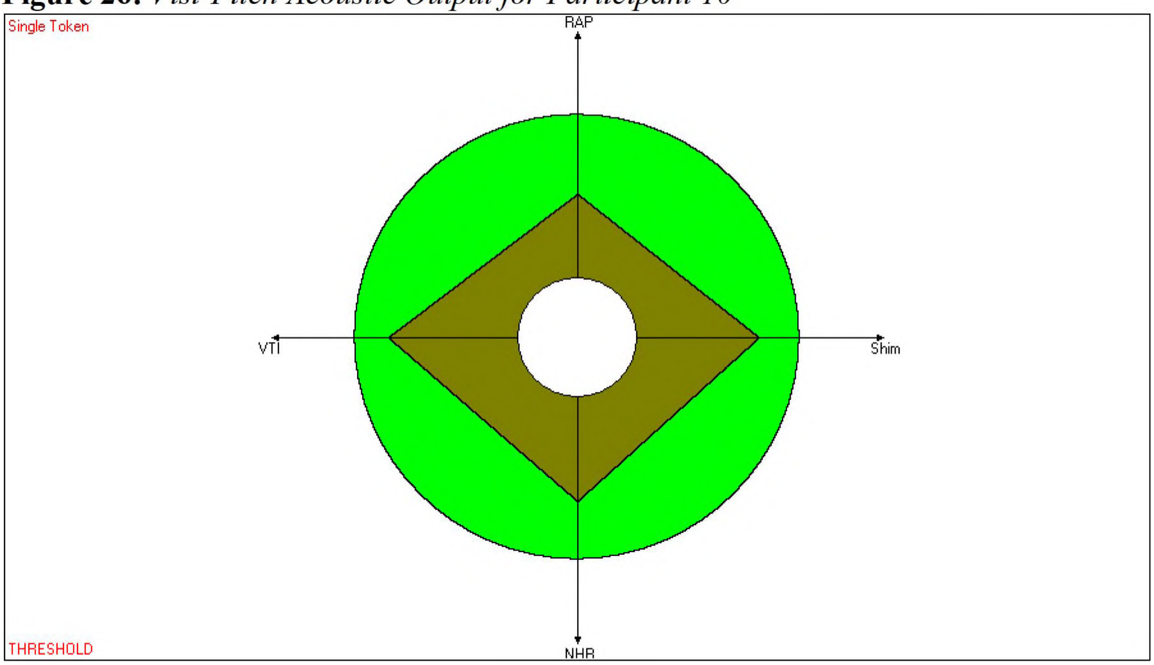


Figure 27a: *Videostroboscopic Imaging of the VF in the Adducted Position*

Figure 27b: *Videostroboscopic Imaging of the VF in the Adducted Position*

Table 26: *Videostroboscopic Descriptive Information for Participant 10*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
10	Present	White Overall, slightly reduced in length (**Figure 27b**)	Even movement medially for adduction Reduced movement overall from the arytenoids	Tissue is pink with trace vascularity Unclear if edema is present in the left pyriform or if this is baseline anatomy

Figure 28a: *FEES Imaging of the Tongue Base for Participant 10*

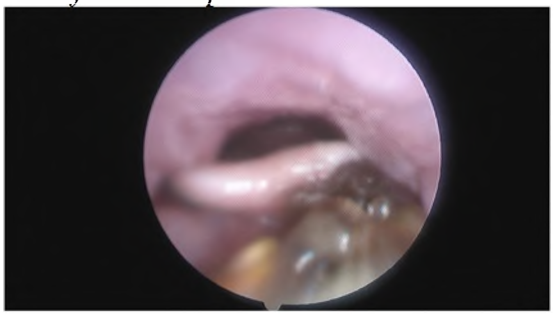


Figure 28b: *FEES Imaging of the Pharyngeal Space for Participant 10*

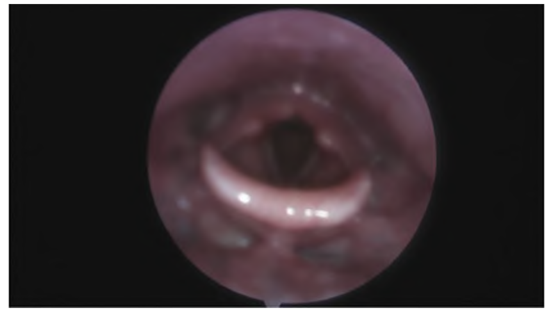


Table 27: *FEES Descriptive Information for Participant 10*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
10	Timely, no premature spillage of the cracker or with water Clear closure of the VF, arytenoids, and beginning movement of the epiglottis posteriorly to cover airway (**Figure 28a**)	No penetration or aspiration noted Trace residue on tongue base from the cracker, cleared with additional swallow	Trace cobblestone appearance of posterior wall (**Figure 28a**)	No noted redness or vascularity All anatomy present

Participant 11

Table 28: *Visi-Pitch Acoustic Values for Participant 11*

Acoustical Information	Value	Norms
Fundamental Frequency	96.873Hz	M:100-150Hz F: 180-250Hz
Shimmer	8.269%	<3.8%
Jitter	0.974%	<1%
Noise-to-Harmonic Ratio	0.170 NHR	Low

Table 28 depicts the acoustical information gather from the Visi Pitch for participant 11. This participant has elevated measures of shimmer and jitter. For NHR, this participant is just under the threshold level. **Figure 29** identifies the elevated measurements marked in red.

Figure 29: *Visi-Pitch Acoustic Output for Participant 11*

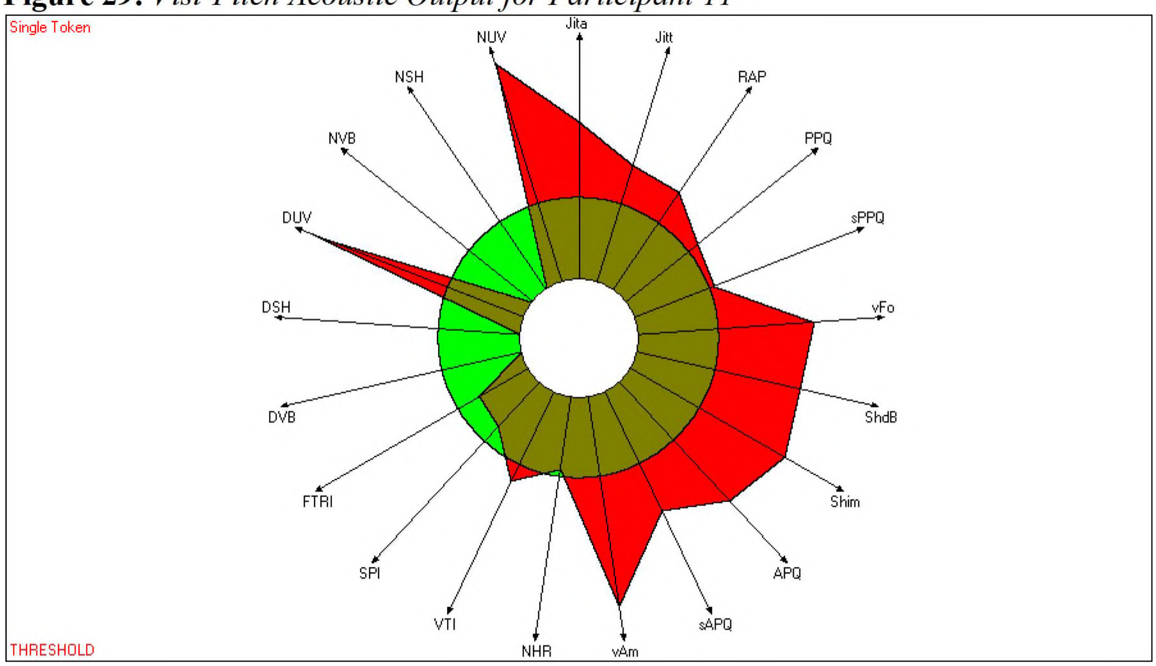


Figure 30a: *Videostroboscopic Imaging of the VF in the Abducted Position*

Figure 30b: *Videostroboscopic Imaging of the VF in the Adducted Position*

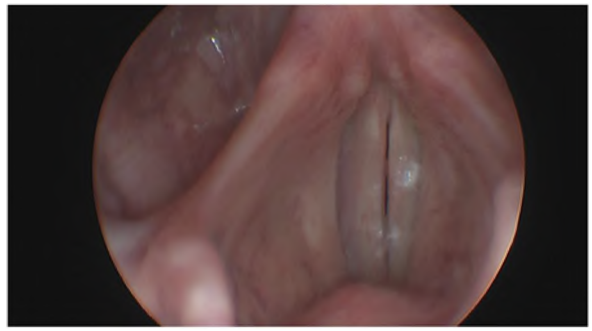


Table 29: *Videostroboscopic Descriptive Information for Participant 11*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
11	Present	Discoloration characterized by vascularity giving the VFs a pink/red tint (**Figure 30b**) Asymmetrical medially with noted mild secretions (**Figure 30a**) Slight thickening of the right VF (**Figure 30b)**	Symmetrical movement of the arytenoids Reduced movement of the left VF possibly secondary to thickening of the right VF	Moderate vascularity of all tissue including the underside of the epiglottis (**Figure 30a** and **Figure 30b**) Moderate edema and redness of the arytenoids (**Figure 30a**) All anatomy present with omega shaped epiglottis

Participant 12

Table 30: *Visi-Pitch Acoustic Values for Participant 12*

Acoustical Information	Value	Norms
Fundamental Frequency	247.996Hz	M:100-150Hz F: 180-250Hz
Shimmer	2.147%	<3.8%
Jitter	0.232%	<1%
Noise-to-Harmonic Ratio	0.109 NHR	Low

Table 30 depicts the acoustical information gather from the Visi Pitch for participant 12. **Figure 31** shows the measurements within normal limits below as all values are within the green circle.

Figure 31: *Visi-Pitch Acoustic Output for Participant 12*

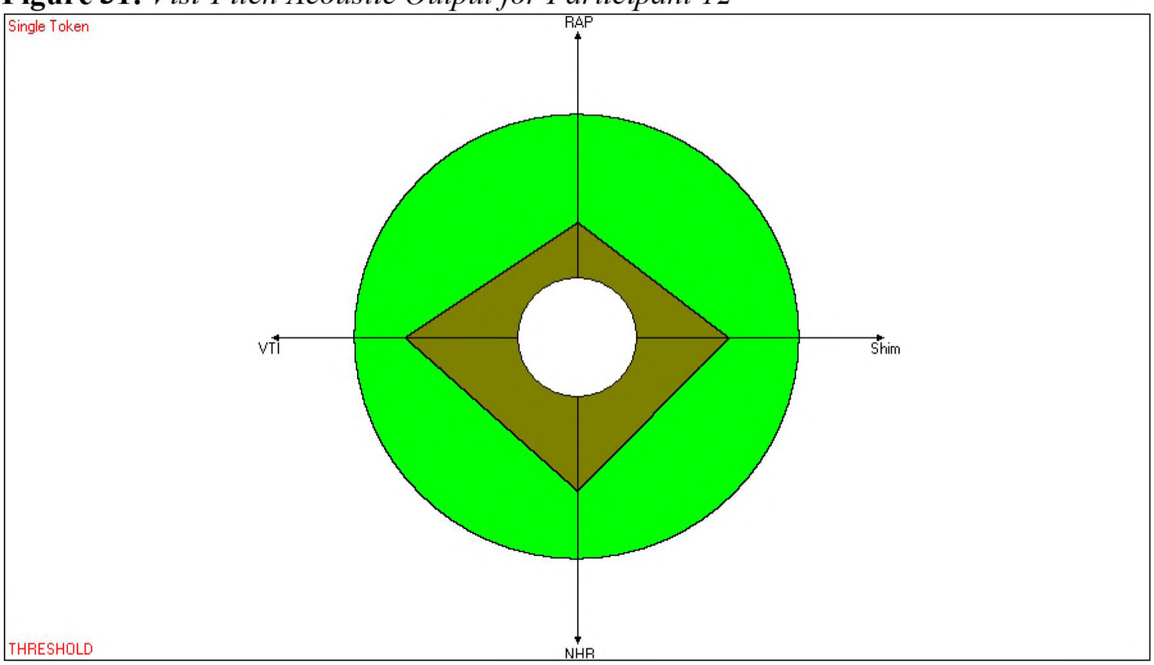


Figure 32a: *Videostroboscopic Imaging of the VF in the Adducted Position*

Figure 32b: *Videostroboscopic Imaging of the VF in the Abducted Position*

Table 31: *Videostroboscopic Descriptive Information for Participant 12*

Participant	Mucosal Wave	VF Appearance	VF Opening and Closure	Surrounding Tissue Appearance
12	Present	White Trace secretions noted (**Figure 32a**)	Symmetrical movement of the arytenoids Symmetrical movement of the VF to midline with good contact during adduction	Mild to moderate vascularity with redness noted on the left side of the tongue base **(Figure 32a)**

Figure 33a: *FEES Imaging of the Pharyngeal Space for Participant 12*

Figure 33b: *FEES Imaging of the Pharyngeal Space for Participant 12*

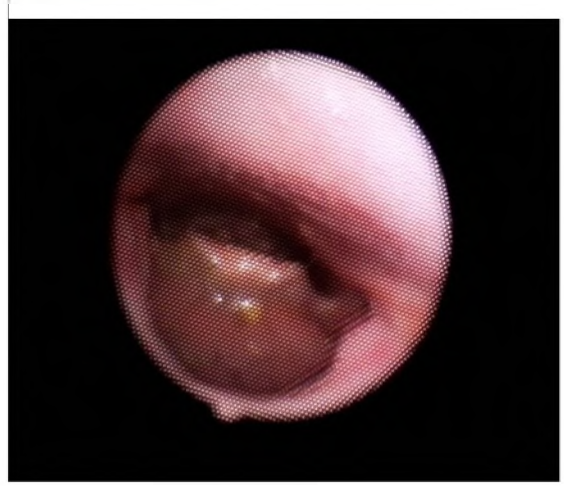


Table 32: *FEES Descriptive Information for Participant 12*

Participant	Swallow onset	Penetration/ Aspiration/ Residue	Pharyngeal Wall Integrity	Surrounding Tissue Appearance
12	Timely with trace premature spillage of the cracker onto the tongue base (**Figure 33b**)	None observed, however, due to cobblestoning of the tongue base it was difficult to obtain a visual of the vallecula after the swallow (**Figure 33a**)	Mild to moderate cobblestone appearance (**Figure 33a**)	Edema and moderate to severe cobblestone appearance of the tongue base (**Figure 33a**) Visualization of the arytenoids and vallecula was difficult to obtain from video

CHAPTER IV

ANALYSIS

The purpose of this current research study was to determine if the presence of GERD can be used as a predictor of voice and swallowing problems. **Table 33** and **Table 34** summarize the data for participants with a diagnosis of GERD compared to those without. The results from the acoustic parameters, Videostroboscopy, and FEES are summarized based on any marked findings. **Table 33** denotes the individuals with a medical diagnosis of GERD and their corresponding results for each of the three measures. An acoustical result is considered marked when the numerical values were higher than the threshold. This is indicated by the green circle from the Visi Pitch output. Borderline acoustical values were noted if the results were inside the green circle but close to the threshold. The videostrobe results are considered marked when greater than trace vascularity, edema, redness, or cobblestoning was noted for each participant. Finally, the FEES results are considered marked when the video recording showed penetration/aspiration or anything above trace residue. When no marked interpretation is present, the results are considered within function limits (WFL) (**Table 33** and **Table 34)**.

Table 33: *Results of Participants with a GERD Diagnosis*

Participant	Acoustic Results	Videostrobe Results	FEES results
1	WFL/heightened jitter	Marked	Marked
2	WFL/heightened shimmer	Marked	Marked
5	WFL/heightened jitter and shimmer	Marked	WFL
6	Marked	Marked	Not obtained
9	Marked	Marked	WFL
12	WFL	Marked	WFL

Table 34 denotes the individuals without a medical diagnosis of GERD and their corresponding results for each of the three measures. Following the same protocol for **Table 33**, the results are summarized below.

Table 34: *Results of Participants with no GERD Diagnosis*

Participant	Acoustic Results	Videostrobe Results	FEES results
3	WFL-heightened peak-to-peak amplitude variation	Marked	WFL
4	Marked	Marked	Not obtained
7	WFL	WFL	WFL-mild cobblestoning of tongue base
8	Marked	Marked	Not obtained
10	WFL	WFL	WFL
11	Marked	Marked	Not obtained

Research Question 1

Is there a visible tissue change in the pharynx related to GERD?

Regarding the first research question, all participants with GERD had marked physical manifestations of the pharynx shown in **Table 33**. For participants with GERD, all participants had identifiable changes in tissue including edema, redness, cobblestone, and vascularity. Videostroboscopy and FEES results ranged from mild to severe in findings. This would indicate a relationship between the presence of GERD and changes in tissue. These results are consistent for participants with recent and long-term GERD diagnoses. This is consistent with research by Lechien et al. (2019) which found higher rates of edema in the areas surrounding the true VF, including the false VF, rather than the true VF themselves.

Analysis of the participants without the diagnosis of GERD who showed acoustical abnormalities (3, 4, 8, and 11) revealed abnormal findings in the tissue of the pharynx. Thus, abnormal acoustical findings appear to be related to tissue changes. It is plausible that participants with no diagnosis of GERD may still be experiencing some form of reflux. The participants without a medical diagnosis of GERD were all in the twenty-age group. As a result of these findings, the hypothesis of physical manifestations in the presence of GERD would appear to be valid. Additionally, it was found that those without GERD also showed physical manifestations when acoustical abnormalities were present. It is noteworthy that these participants with abnormalities and without GERD were all in their twenties. This raises the question of the possibility of GERD symptoms being present in younger individuals as indicated by the abnormal acoustic findings and visual appearance of the laryngeal tissue. This might suggest the possibility that acoustical measurements could be used as a predictor of physical manifestations of laryngeal changes.

Research Question 2

Are there any corresponding acoustic abnormalities (F0, shimmer, and jitter) in the presence of GERD?

Regarding the second research question, some participants with GERD showed abnormal acoustical measures. Of the six participants with GERD, five had heightened acoustical measurements (three past the threshold), all six had marked results through visualization of the videostrobe, and two participants had marked findings as revealed through the FEES. Of these six participants, two individuals were over 40 years old, one male and one female, who had acoustical measurements beyond the threshold. The other four participants (1, 2, 5, and 12) were all in their twenties.

Younger participants had WFL acoustic measurements, although they showed heightened values in one or more areas demonstrated in **Table 33**. This might partly support the hypothesis that there are associated abnormalities in participants with GERD for acoustical measurements. This is compared to four participants in their twenties, who had a more recent diagnosis of GERD, even though heightened values were noted in all but participant 12. These results appear to be consistent with the findings of Oguz et al. (2007), and Lechien et al. (2019) all of whom found abnormal acoustical measurements in individuals with GERD. The results of these studies are more robust as their sample set included a larger pool and individuals forty years and older.

All participants in the no-GERD group who had marked results in acoustical measurements also showed marked results from the videostrobe examination (**Table 34)**.

These markers appear to coincide with the presence of acid reflux as demonstrated by Oguz et al. (2007), Lechien et al. (2019), and Ganesan et al. (2017). However, in this current study, it cannot be concluded that GERD can be used as a predictor of abnormal acoustical findings when compared to those participants without the diagnosis. For example, in this group, the younger participants did not have abnormal acoustic readings compared to the two older participants who had. Interestingly, the two older adults who had the diagnosis for longer periods exhibited impaired acoustic findings. This could very well be related to the length of time the male participant had the diagnosis of GERD for over ten years, and the female had the diagnosis for four years. In addition, both participants continued to use their voices as part of their occupation. The male participant was a public speaker, whereas the female was a teacher and had also undergone thyroid surgery.

Research Question 3

Are there any associated swallowing difficulties?

The final research question aimed to identify any abnormal observations in swallowing as depicted from the FEES in participants with GERD. Of the six participants in the GERD group, two (1, and 2) showed marked results. These included residue and penetration before the swallow. Of note, these participants had moderate to severe cobblestone appearance of the pharyngeal wall and tongue base. This would seem to associate the tissue changes seen under Videostroboscopy with observable swallowing findings. Participant 12 also had moderate to severe cobblestoning of the tongue base but had trace premature spillage. All individuals in this study appear to have adequate swallow function. No results indicated that a change in diet consistency or modifications is necessary other than continued acid reflux precautions. However, as found by Aviv et al.

(2000), sensory deficits are a possible result of GERD/LPR in adults over forty. This means unmanaged or severe GERD could lead to more significant medical complications as the individual ages. Participants in the no GERD group had unremarkable findings for the FEES measurements.

CHAPTER V

CONCLUSION

This retrospective study aimed to answer three questions about the influence of GERD on swallowing and vocal parameters. This preliminary study resulted in four main findings. The first trend was seen with participants 6 and 9. These participants had complaints of vocal strain and or pain when speaking. They also had a diagnosis of GERD for a longer period. Although the acoustical abnormalities were not as significant as revealed by acoustical output from the Visi-Pitch as other participants, they showed greater perceptual abnormalities. These abnormalities included complaints of significant vocal quality changes such as hoarseness and vocal strain. These two older participants also had occupations that involved speaking excessively. This was a finding by Ganesan et al. (2017) that lifestyle plays a role in the severity of vocal concerns. This would indicate that adults who had a diagnosis of GERD over a longer period could show more perceptual findings later in life compared to younger participants that only show minor acoustical abnormalities. Additionally, this trend might be supportive of the notion that early treatment and management of GERD might reduce deficits in swallowing and voice.

The second finding is specific to the young adult participants with marked swallowing results (1, 2). These participants had more defined physical manifestations in tissue changes of the pharynx. As previously stated, these results are not considered medically significant at this time. However, there was a trend of more severe tissue changes resulting in notable findings during their swallows. This could indicate that more defined changes in tissue may result in swallowing problems in the future. The third finding was that the predictor of these physical manifestations was not necessarily due to the presence of GERD, but rather abnormal acoustical findings. All participants with GERD showed changes in tissue. The participants without GERD but with abnormal acoustical measures also showed changes in tissue. It is because of this, it appears in this study, that acoustical abnormalities are a better predictor of tissue changes compared to GERD. This was provocative because one would expect that GERD would be the predictor of the tissue changes due to the acidic nature of GERD. Therefore, the presence of objective measures is important when completing a voice evaluation compared to only subjective or perceptual observations. Participant 6, who was a 45-year-old female exhibited significant perceptual vocal quality changes. However, the corresponding acoustical measures were only slightly above the threshold found in **Figure 16.** This contrasted with the results of individuals in the younger, no-GERD group, who showed remarkable above threshold levels. This could be a conundrum simply because the number of participants in this study was extremely small. Nevertheless, it does provide fodder for thought.

The final seminal finding of this study is the number of abnormalities in the younger group. Most studies that have researched GERD and the role it plays on the voice or swallowing were completed with older participants. The participants for this study were selected only based on the criteria that they had data points from at least two of the instruments in the voice and swallowing lab. This study found that most younger adults showed signs of reflux regardless of an official medical diagnosis. This could be due to many factors including stress level, diet, and lifestyle habits. Regardless, these results indicate that if not treated early, a person with GERD may eventually develop more pronounced manifestations from a speech and swallowing perspective. These results might suggest that young people show physical manifestations at a higher rate than originally expected.

Limitations

There were several noteworthy limitations to this study. Because the study was retrospective, several variables could not be controlled. For example, important pieces of data were missing for some individuals. No FEES data was collected for participants 4, 6, 8, and 11. This missing data could have skewed any findings. Additionally, the sample size of this data was too small. So, any results that could be gleaned from the study may very well be attributed to individual differences rather than a trend. Moreover, inclusion criteria for the participants were limited to studies that had been completed and stored in the voice and swallowing lab. Because of this, the investigators had little control over the types of participants used in this study. This included information such as accuracy of age, past medical history, and gender. Ideally, the participants would have met specific inclusion/exclusion criteria to definitively answer the research questions. Another limitation of this study was reduced control in the data collection including standardization of the procedure. Ideally, there would have been an in-take form detailing the past medical history and specific questions related to voice and swallowing. The third limitation was the equipment used for the data. It is possible the equipment was not able to pick up more subtle changes. A future study might use newer equipment that would be more sensitive to tissue changes for accuracy. Additionally, because the data were collected without a specific study in mind, certain settings were not turned on resulting in a reduced amount of data points for objective analysis. Specifically, information regarding the mucosal wave and various measurements for the Visi Pitch.

For FEES, the scope that was used was a fiberoptic cable resulting in a grainier image. More recent cables are not fiberoptic and allow for thirty frames per second during analysis. Although no participants showed functional changes resulting in diet consistency restrictions, newer equipment might aid in the descriptive analysis due to the quality. Lastly, this study used a sample size of twelve due to the retrospective nature and is limited to the data previously collected. For more definitive data, the sample size would need to increase and have stricter guidelines such as a study of only young adults or only older adults. More specific information regarding past medical history and length of diagnosis would also be beneficial to strengthen the findings concerning the influence of GERD on voice and swallowing.

Future Directions

The results of this study indicate that there is a lot more to be found regarding GERD and its effect on voice and swallowing. Research could continue to look at findings related to age and length of diagnosis. Specifically, are there acoustical measures that may indicate the presence of GERD? There appeared to be a trend of higher measurements of peak-to-peak amplitude, but this measurement was not turned on in the settings for all participants. Moving toward the videostrobe findings, do perceptual changes in the voice often result in abnormal acoustical or videostrobe findings? Participant 6 complained of vocal strain and changes in vocal quality more recently, yet the acoustical measurements were not as significant as other participants without these new complaints. More research should be done regarding perceptual vocal quality and corresponding acoustical measurements to determine how GERD influences these areas. As stated earlier, more standardized procedures should be done regarding the data collection.

Research should continue to obtain information about the influence of GERD on swallowing and sensory functioning. Is there a way to quantify the physical tissue changes that result in functional changes and what is that threshold? Additionally, what role does age or length of diagnosis have on the function of the tissue? Both of these questions would allow for a better understanding of GERD and how many people might need the services of a speech therapist in the future. It is known that functional changes occur over the lifespan and as adults age, resulting in changes in the swallow. But future research should look to explore the possibility of the acceleration of GERD as a function of age.

Overall, this preliminary study found trends in both young and older adults consistent with research in the areas of voice and swallowing. This study also combined the use of three instrumentations to help answer the three research questions. The use of the measurements from the Visi Pitch, videostrobe, and FEES allows for a speech pathologist to begin to obtain the whole picture of the patient. It is important that the speech therapist does their due diligence including obtaining the proper referrals such as a GI or ENT when necessary. Working with individuals with GERD is complex, requiring an interdisciplinary team in order to best serve the patient.

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