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Variations in Lingual Pressure during Saliva Swallows between a Healthy Adult Female and a Female with Head and Neck Cancer

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Variations in Lingual Pressure during Saliva Swallows between a Healthy Adult Female and an Adult Female with Head and Neck Cancer

A thesis submitted to the
Graduate School
of the University of Cincinnati
in partial fulfillment of the
requirements for the degree of

Master of Arts

in the Department of Communication
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by

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Abstract

Dysphagia is among the most serious and common disorders experienced by elderly adults and adults who have undergone treatment for oral-pharyngeal cancer. Research has demonstrated that adequate lingual pressure is one of the most significant factors in one’s ability to swallow safely, assisting in the avoidance of penetration and aspiration of food and liquid. Lingual pressures decrease, however, with age and with disease-related processes. This study examined the lingual pressure measurements during saliva swallows of a healthy adult female (participant one) and an adult female who underwent a partial glossectomy with free flap reconstruction and radiation treatment (participant two). The KayPENTAX Swallowing Signals Lab (Kay Elemetrics, Lincoln Park, NJ) was used to measure peak lingual pressure during saliva swallows, using three-bulb tongue arrays, so that comparisons between the two participants could be made. The results revealed that the mean lingual pressure measurements during saliva swallows between the two participants varied greatly. For participant one, mean anterior lingual pressures were 106.4 and 108.4 (time period 1 and 2), while the mean posterior lingual pressures were 323 and 373.6 (time period 1 and 2). Participant two’s mean anterior lingual pressures were 30.4 and 11.6 (time period 1 and 2), and her mean posterior lingual pressures were 58.6 and 66.2 (time period 1 and 2). The peak lingual pressures for participant one and participant two are similar to the peak lingual pressures of healthy adults and adults who have undergone head and neck cancer treatment. The posterior tongue pressures were greater than the anterior tongue positions in both participants, as the posterior tongue’s role is to propel the bolus posteriorly into the esophagus with
significant force against the posterior pharyngeal wall. Despite participant two’s reduction in lingual pressure measurements in comparison to participant one, the trend for the posterior lingual pressure to be greater than the anterior tongue pressure still remained in this participant’s physiology of swallow. Future study could examine a larger population of healthy adults and head and neck cancer adults to determine true significance between lingual measurements, as well as take into consideration type of head and neck cancer and degree of surgical resection and chemoradiation treatment.
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Average Peak Lingual Pressure during Saliva Swallows
CHAPTER 1

Introduction

Dysphagia was once defined most simply as the difficulty of moving food from the mouth to the stomach. Researchers have since expanded that definition to include all of the behavioral, sensory, and preliminary motor acts that prepare for a swallow, including one’s cognitive awareness of the upcoming eating situation and environment, visual recognition of food, and the physiologic responses to the smell and presence of food (such as increased salivation). Dysphagia is among the most serious and common disorders, including its associated life-threatening effects, such as pneumonia, malnutrition, and dehydration, experienced by elderly adults. As many as 40 percent of the adult population aged 60 and older currently are diagnosed with dysphagia (Robbins, Gangnon, Theis, Kays, Hewitt, & Hind, 2005). This number is expected to increase significantly with the rise in the geriatric population over the next 10 years.

Pneumonia in elderly adults is one of the most debilitating effects of dysphagia; it is the fifth leading cause of death in adults aged 65 and older, and is the third leading cause of death in adults aged 85 and older (Robbins et al., 2005). At least 50 percent of patients in nursing homes are dysphagic (Robbins, Levine, Wood, Roecker, & Luschei, 1995). Morbidity and mortality are now recognized more frequently as major geriatric health problems, as the costs associated with management of problems resulting from dysphagia increase from the individual’s dependence on others.

Due to the national elderly population’s exponential growth, medical professionals are seeing an increase in chronic age-related conditions such as diabetes, congestive heart failure, and frailty (oftentimes resulting in immobility). Geriatric
medicine has an even greater focus now on sarcopenia, the pervasive loss of muscle mass in normal aging resulting in reduced muscle strength (Robbins et al., 2005). Functional decline is a known result of sarcopenia in the striated muscles of the limbs and extremities, and is being witnessed more often in the smaller striated muscle groups, such as those involved in swallowing (Robbins et al., 2005). Due to age-related loss in muscle mass, healthy elderly individuals have an increased prevalence of dysphagia. Unless strength can be recovered or maintained, sarcopenia can result in a less effective (i.e., less safe) swallow (Hewitt, Hind, Kays, Nicosia, Doyle, Tompkins, et al., 2008).

Lingual functioning, as related to feeding and swallowing, has been identified to change as a function of neurological insult or injury, disease, and/or illness. In addition, lingual strength has been identified to decrease with age; however, the impact of age-related versus disease-related factors regarding swallow physiology has not been systematically studied. Many patients with dysphagia after such injuries or insults, such as head and neck cancer, frequently exhibit signs of aspiration, eating dependency, diminished potential for dysphagia rehabilitation, and often require lengthier hospital stays and/or nursing home placements (Robbins, Kays, Gangnon, Hind, Hewitt, Gentry, et al., 2007). In addition, patients who have undergone a partial glossectomy with chemotherapy and radiation therapy are at great risk for dysphagia due to the anatomic and physiologic changes that occur following such intense treatment and surgical intervention.

There are new data emerging that characterizes the affects of healthy aging on peripheral swallowing physiology, specifically as related to lingual pressure. Adequate lingual pressure is required to initiate the coordinated and timed series of neuromuscular
phyiologic events that occur during swallowing; however, the specific range of normal lingual pressure measures, corresponding to regions of the tongue during different swallowing tasks, is not fully understood. Equipment, such as the Iowa Oral Pressure Instrument (IOPI Northwest, Carnation, WA) and the KayPENTAX Swallowing Signals Lab (Kay Elemetrics, Lincoln Park, NJ), is now available that readily measures lingual pressure at different regions of the tongue during swallowing. Currently, researchers and clinicians typically use each dysphagic individual as their own control relying on a change in the direction of increased lingual pressure as an indication of improvement. This trend poses challenges both for the researcher and clinician who questions the reliability and variability of baseline lingual pressures and warrants the need to establish a normative database against which values from individuals with dysphagia can be compared.

Statement of the Problem

Because of the difficulties with deglutition that head and neck cancer patients experience, assessment and treatment of dysphagia in these individuals is complex and involves extensive use of behavioral and instrumental components. Much of the existing interpretation of data used during assessment and treatment planning is based on information from dysphagic individuals. Less is known about the normal variants of swallowing across the lifespan, particularly in the area of physiologic factors that lend themselves to instrumental analyses (e.g., lingual pressure patterns of anterior and posterior tongue). Direct comparisons of individuals post (or undergoing) treatment for lingual cancer with age- and gender-matched healthy individuals are not available. Due to the importance of lingual musculature in the safety of swallowing physiology, research
focusing on the variations in lingual pressure as a result of oropharyngeal cancer is beneficial. Thus, the purpose of this study is to examine the differences in lingual pressure measurements between an adult female who underwent a partial glossectomy with those of a healthy individual. The outcome of this research will be a first step in advancing the knowledge of how comparing normal and disordered lingual pressure measures can aid the assessment and treatment of dysphagia.
CHAPTER 2

Background Literature Review

Swallowing is a complex activity comprising distributed sensorimotor neural circuits in both cerebral hemispheres. The corticobulbar tracts transmit information to the pons and medulla, interacting then with the muscles of swallowing. The propulsion of a bolus from the oral cavity, specifically when the bolus is larger in volume and varies in viscosity, is done with increased force, which then influences pharyngeal swallow events and timing. Generating lingual pressure is important for bolus clearance in the pharynx; inadequate lingual pressure may result in pharyngeal residue, putting the individual at risk for penetration and/or aspiration. Inadequate lingual pressure over a period of time can further result in malnutrition, pneumonia, and dehydration as the individual receives inadequate and reduced amounts of nutrition orally (Robbins et al., 1995). Taking into account all of the intrinsic and extrinsic muscles involved in the physiology of the swallow, coupled with the sensory and motor information relayed from the cortex to the muscles themselves, it is understandable how any disruption in the system will contribute to a disordered swallow. Restoration of a safe swallow depends partially on any recovery of neuromuscular factors, including muscle (i.e., lingual) strength.

*Lingu al Pressure Measures and Swallow Function in Healthy Adults*

Little research has been conducted examining the relationship between lingual strength and pressures generated during swallowing; however, the data that has been obtained strongly suggest that lingual pressures do influence the effectiveness of the swallow. Robbins et al. (1995) found that peak lingual pressures decline with age;
Nicosia, Hind, Roecker, Carnes, & Robbins (2000) later proposed that age-related decline in overall skeletal muscle strength, in addition to data showing increased amyloid deposits in the lingual tissues of elderly individuals, suggest that similar changes to those reported in arm and leg musculature could be occurring in the tongue as well. Further, instability in peak swallowing pressures, or the highest pressures generated during swallowing, in elderly individuals coupled with increased oral phase duration led researchers to suggest that elderly individuals may need additional time to build up pressure in order to transmit a bolus safely into the pharynx. In 2007, Robbins et al. found that in participants undergoing an 8-week lingual strengthening program, lingual strength increased along with lingual pressures generated during a swallow. In addition, bolus flow kinematics characterized by a reduction in pharyngeal residue and proper airway protection measures, along with increased oral transit time, were observed.

Building strength in lingual musculature has crucial clinical implications, especially when considering oral intake in adults as they age. Using the Iowa Oral Pressure Instrument (IOPI Northwest, Carnation, WA), Nicosia et al. (2000) found that premature entry of a thin liquid bolus into the pharynx often accompanied a pattern of lingual pressure at all three points (anterior, middle, and posterior) of the pressure sensor bulbs (bulbs that sense and measure pressure generated by the tongue during swallow tasks) on the tongue bulb arrays. Tongue bulb arrays are held in place along the midline of the hard palate while the participant performs various swallow tasks; the bulbs on the array measure the lingual pressure generated during the swallow task. The pattern found by Nicosia et al. (2000) showed that the initial lingual pressure peak propelled the bolus partially into the pharynx before the airway protection reflex was triggered; the material
was then aspirated into the larynx. However, they later discussed that the underlying cause of such lingual behavior and resulting aspiration was unclear. Elderly individuals often have multifaceted medical conditions, which could all contribute to dysphagia; hence, Nicosia and colleagues suggested that future research evaluate the relationship between age-related physiological changes in such a population, and the swallowing patterns and lingual pressure changes that occur as a result.

**Dysphagia in the Head and Neck Cancer Population**

Disease-related changes in the swallow process occurring from head and neck cancer often cause a multitude of problems related to swallowing and efficiency of swallowing physiology. Dysphagia can be primary as a result of the disease, or secondary to the disease due to treatments used, such as radiation or chemotherapy. For example, individuals who have lingual cancer with large, bulky lesions will inherently experience some dysphagic symptoms due to the changes in their oral anatomy and the presence of such a large lesion, affecting the tongue’s ability to move in a necessary pattern for bolus formation and propulsion; these individuals are experiencing dysphagia as a result of the disease itself. These same individuals will experience dysphagia immediately post-operatively as a result of the extent of surgical resection, edema, and loss of lingual tissue.

Common sites of head and neck cancer include the oral cavity, tongue, pharynx, larynx, and pharyngeal musculature (Ball, Idel, Cotton, & Perry, 2006). It is well known that cancer treatments involving chemotherapy and radiation have adverse effects on lingual function, thus impacting swallowing physiology and effectiveness. Patients with
tongue base resection have experienced decreased volume in the base of the tongue, which is then unavailable for pressure generation in the oral phase of swallowing. Ball et al. (2006) documented that combination chemotherapy and radiation treatment significantly decreased tongue strength in oral and oropharyngeal cancer patients; chemotherapy treatments weakened musculature, and radiation led to tissue necrosis, which could later extend into fibrosis, reducing the overall range of lingual movements. In fact, studies regarding post-radiation treatment swallowing outcomes identified increased space between the tongue base and the posterior pharyngeal wall when compared to normal participants (Ball et al., 2006). Increased space between these structures could affect the ability of the tongue to efficiently propel the bolus to the oropharynx, which affects subsequent pharyngeal constriction to propel the bolus inferiorly to the esophagus, thus increasing the risk for penetration and aspiration in these individuals (Ball et al., 2006).

Head and neck cancer patients also frequently experience xerostomia, or reduced flow of saliva, as a common occurrence following radiation treatment. In addition, these patients often experience edema and occasional mucositis (sores in the mouth) (Lazarus, Logemann, Pauloski, Colangelo, Kahrilas, Mittal, et al., 1996). Because of the nature of radiation, the changes in salivation are permanent, and medications to supplement xerostomia are usually only partially beneficial. Xerostomia alone can affect swallowing, contributing to reduced speed of tongue movement causing a delay in oral transit time, and changes in tongue movement contributing to a delay in pharyngeal trigger of the swallow (Lazarus et al., 1996). Fibrosis, or fascia and muscle tissue stiffness, also occurs due to damage of small blood vessels in the area that received radiation; this can cause
residue collection in the pharynx after the swallow, further increasing the risk for penetration and aspiration.

Due to all of the changes in anatomy and physiology of the swallow following head and neck cancer treatments, clinicians and researchers working with these individuals should be aware of the extent of impact on swallowing function. Based on the various types of medical and surgical interventions, treatment for dysphagia in this population will vary.

*Medical and Surgical Treatment of Head and Neck Cancer: Impact on Swallowing Function*

Several studies have been conducted examining the differences between individuals with oropharyngeal cancer who underwent surgical intervention alone versus those who underwent surgical intervention with additional chemotherapy and/or radiation treatment. Pauloski collaborated with Rademaker, Logemann, and Colangelo (1998) to study the effects that radiation treatment had on swallowing function for 18 patients diagnosed with oral and oropharyngeal cancer. Half of the participants received surgical intervention with radiation therapy; the remaining half received only surgical intervention. The participants were matched as closely as possible based on their percentage of lingual resection, tongue base resection, location of resection, and the reconstruction method used. The authors studied the participants’ swallowing functions pre-treatment, and again at 1 month, 3 months, 6 months, and 12 months following surgery. The results indicated that the participants who received only the radiation therapy demonstrated significantly decreased oral and pharyngeal swallowing effectiveness. This was characterized by noticeably increased oral transit times on
thicker boluses, increased residue in the pharynx, and reduced cricopharyngeal opening duration. The authors proposed that these changes in swallowing function could have resulted from edema, fibrosis, and/or xerostomia due to radiation therapy.

Lazarus, Logemann, Pauloski, Rademaker, Larson, Mittal, et al. (2000) added to earlier findings of the adverse affect of radiation on swallowing by examining lingual function and its relation to swallowing in 13 head and neck cancer participants before and after primary treatment with combined chemotherapy and radiation treatment. They compared the data to 13 age- and gender-matched control participants. The fundamental goal was to examine the effects of chemotherapy and radiation on lingual strength and endurance in participants with head and neck cancer, and to then examine the relationship between their lingual function and swallowing. Using the Iowa Oral Pressure Instrument (IOPI Northwest, Carnation, WA), the authors measured the lingual pressures of each participant prior to and following chemoradiation treatment. The authors observed that primary radiation for oral and oropharyngeal cancer can negatively influence the ability to propel food from the anterior tongue to posterior pharynx and into the esophagus, particularly when swallowing thicker consistencies. Even when the participants were able to demonstrate normal lingual rotation and function during oral motor examination and non-swallowing movements, they still demonstrated difficulty with posterior bolus propulsion, resulting in base of tongue and oral cavity residue. As expected, the lingual strength measurements were higher for the control group than for the head and neck cancer group. These findings supported the authors’ hypotheses that lingual strength and oropharyngeal swallowing was adversely affected by chemotherapy and radiation therapy.
Free Flap and Primary Closure Reconstructive Methods

Numerous researchers have questioned the type of reconstructive method and overall effectiveness in the oropharyngeal cancer population. In 1993, Logemann, Pauloski, Rademaker, McConnel, Heiser, Cardinale, et al. examined swallowing function in 11 participants who underwent surgical resection of greater than 1 centimeter of tongue base, tonsil, and faucial pillar with a mandibulectomy on the side of the tumor, with reconstruction by primary closure. Primary closure of a partial glossectomy involves use of the remaining lingual tissue, without surgical grafting from other tissues, to close the wound; flap reconstruction, on the other hand, involves tissue grafting and surgical application to the remaining lingual tissue in order to combine the edges of a larger lingual resection. This area of resection at the tongue base, tonsil, and faucial pillar is one of the most common in the oral cavity and has the potential to affect the oral and pharyngeal phases of swallowing; when the musculature of the tongue is altered, it follows that bolus containment and propulsion will be affected to some degree. Results were compared with similar data on participants who had undergone anterior tongue and floor of mouth resection with a distal flap closure. In both groups, postoperative swallowing effectiveness was decreased with minimal improvement after 3 months. Specifically, all participants demonstrated deficits in oral and pharyngeal swallowing, reflected by increased oral and pharyngeal residue. These results emphasized the importance of lingual function in bolus propulsion cleanly (i.e., without oropharyngeal residue) from the oral cavity to the esophagus.

The participants’ greatest challenge in Logemann et al.’s study (1993) was in moving food from the oral cavity to the pharynx on paste and masticated consistencies.
These consistencies tended to require increased lingual pressure than liquids, while liquids tended to move more quickly with just gravity alone. In contrast, however, the participants’ airway closure and cricopharyngeal opening were normal following surgery. Swallowing function after 3 months for all participants with tonsil and base of tongue resection decreased noticeably for pharyngeal transit time, delayed pharyngeal trigger, and oral and pharyngeal residue clearance. The researchers hypothesized that these changes may have resulted from xerostomia and fibrosis from radiation therapy to the oral cavity and pharynx.

Pauloski, Logemann, Rademaker, McConnel, Heiser, Cardinale, et al. (1993) examined the swallowing function of 16 participants following anterior tongue resection and floor of mouth resection, with reconstruction using a distal flap; seven participants also received postoperative radiation therapy. Swallow function data was collected at 1 month and 3 months postoperatively. The researchers used videofluoroscopy to determine oropharyngeal swallow efficiency (OPSE). OPSE is a global measure of the safety and speed of a participant’s swallow, and it is calculated by measuring total oral and pharyngeal transit time, which is then divided by the percentage of the bolus swallowed (i.e., amount of residue remaining). Their results indicated that the participants demonstrated significant functional impairment in swallowing postoperatively, with little to no improvement 3 months postoperatively. The participants demonstrated oral residues exceeding 50 percent, and OPSE measures less than 30. These scores indicate a patient population that was severely impaired.

McConnel, Pauloski, Logemann, Rademaker, Colangelo, Shedd, et al. (1998) evaluated the functional results of swallowing in oropharyngeal cancer participants who
received primary closure versus those who received flap reconstruction (i.e., primary closure, distal myocutaneous flap, and microvascular free flap). The authors studied swallowing function using videofluoroscopic imaging prior to treatment and 3 months after the reconstruction surgery. Compared to those who received distal flap reconstruction, participants who underwent primary closure reconstruction were more efficient in swallowing liquid boluses, had less residue in the pharynx, and had increased oral transit times with paste consistencies. There were no significant differences between swallow function in participants who received distal versus free flap surgery. The authors concluded that contrary to pre-existing theories surrounding oral and oropharyngeal reconstruction, primary closure techniques resulted in equal or better swallow functions than flap reconstruction.

In 2000, Furia, Carrara-de Angelis, Martins, Barros, Carneiro, and Kowalski used videofluoroscopic testing to evaluate the effectiveness of swallowing after participants underwent total and partial glossectomies. Their goals included characterizing the swallowing patterns in these participants and defining the limits and compensatory strategies used while examining them under videofluoroscopy. Five of the 15 participants underwent partial glossectomy. Only one of the five participants had a tongue flap reconstruction (without chemotherapy or radiation treatment), while one participant had chemotherapy or radiation prior to and following surgery, and one participant had radiation treatment post-surgery. The authors discovered that all participants who underwent a partial glossectomy experienced difficulties with bolus formation orally, as well as propulsion of the bolus from the anterior to posterior oral cavity. Further, they found that these participants demonstrated increased oral transit
time, more evidently with thicker consistencies, stasis in the oral cavity, and increased number of swallows required to clear a bolus. Furia and colleagues discussed that glossectomies commonly result in dysphagia, and the severity of dysphagia depended on the extent of the resection, mobility of remaining anatomy, type of reconstruction, involvement of other nearby anatomic structures, and the patient’s motivation and adaptability to the surgery results.

Uwiera, Seikaly, Rieger, Chau, and Harris (2004) conducted a study on the functional outcomes of swallowing in 11 participants who received a partial glossectomy with free flap reconstruction. The authors gathered swallowing data preoperatively, immediately following surgery, and again following radiation treatment. Consistent with prior research, the results showed that there were fewer occurrences of laryngeal penetration on thin liquids immediately postoperatively, and no significant differences were found with laryngeal penetration with pudding or solid consistencies. Aspiration was not detected at any of the assessment periods, nor was there a significant difference discovered in oral or oral preparatory phases across assessment periods. The authors concluded that the free flap reconstruction provided functional swallowing outcomes in those participants who received a partial glossectomy.

Surgical Intervention and Chemotherapy/Radiation Treatment

Mittal, Pauloski, Haraf, Pelzer, Argiris, Vokes, et al. (2003) also examined the effects of surgery on head and neck cancer participants, and similarly discussed that dysphagia following surgery alone depended on resection amount, structures resected, and the method of reconstruction used. They concluded that although primary surgical closure (with no surgical grafting) appeared throughout literature to result in a more
effective swallow function, this type of reconstruction cannot be performed with a large lingual resection; rather, larger free flap reconstructions were necessary for greater tongue resections. Surgical intervention and radiation treatment were then evaluated in combination. The authors stated that dysphagia presenting in the immediate post-operative period depended on the tumor site, extent of resection, and reconstruction method used. After 6 months, these participants experienced dysphagia due to complications from neuromuscular damage and fibrosis of oropharyngeal tissues (Mittal et al., 2003).

When examining radiation therapy alone, the authors’ review of literature concluded that radiation-induced xerostomia often resulted in reduced lubrication of the bolus. The xerostomia confounded the additional difficulties caused by radiation therapy, which included increased oropharyngeal transit time, incoordination of bolus movement, reduced tongue-base contact with posterior pharyngeal wall, restricted laryngeal and hyoid elevation/movement, and consistent pharyngeal residue and aspiration. Dysphagia following combination chemotherapy and radiation was typically due to the affect of chemical agents on muscle fibers to both kill the malignant tumor and increase the sensitivity of the tissue to radiation. High volumes of radiation were required to eliminate the tumors. These participants exhibited similar difficulties and impairments as those who received radiation therapy alone; therefore, it was difficult for the researchers to determine the individual contributions of chemotherapy and radiation treatment in the occurrence of dysphagia in this patient population. Dysphagia occurred in all participants who underwent surgery and those who underwent surgery and radiation treatment, as well as combined chemotherapy and radiation following surgery. For all groups, the
extent of the tumor and resection, as well as the reconstruction method used, were the most critical factors for dysphagia and overall prognosis (Mittal et al., 2003).

Lazarus (2006) further advanced the literature and evaluated types of lingual impairment and oropharyngeal swallowing impairment following head and neck cancer treatment, focusing specifically on surgery and primary chemotherapy and radiation protocols. Lazarus discussed that lingual impairment in patients treated surgically could include reduced range of motion, reduced oral control, and reduced ability to manipulate, seal, and propel a bolus posteriorly into the pharynx. This impairment could also result in prolonged oral transit times, oral residue, and increased number of swallows required to clear a bolus. The effects of radiation treatment were also described, including tissue fibrosis as a common effect, contributing to dysphagia in most participants. Lazarus discovered that those participants who were treated with primary chemotherapy and radiation had impairments in the oral phase of swallowing and demonstrated reduced range of tongue motion, decreased lingual strength, bolus formation difficulties, prolonged oral transit times, and increased oral residue.

The following year, Lazarus joined with Logemann, Pauloski, Rademaker, Helenowski, Vonesh, MacCracken, et al. (2007) to examine swallowing and lingual pressure in participants with oral cancer, examining the effects of radiation with or without chemotherapy in these participants. The authors examined the participants’ lingual strength and swallowing prior to treatment, and again at 1 month, 3 months, 6 months, and 12 months following treatment. A total of 46 participants were involved in the study, and all underwent lingual strength assessment using the Iowa Oral Pressure Instrument (IOPI Northwest, Carnation, WA) to determine maximum isometric pressure
generation. Results of the study revealed that the participants’ average maximum tongue strength was not significantly reduced immediately following treatment; however, the participants exhibited noticeable decreases at the 6- and 12-month assessments. The authors postulated that the lack of tongue strength reduction immediately following treatment could have been a result of changes in tumor bulk pre- versus post-treatment. The presence of the tumor prior to chemotherapy and radiation most likely caused pain and thus reduced lingual strength due to its mere infringement upon the oral cavity structures. The side effects of the treatment may have thus been countered by the tumor’s shrinking and the participants’ resulting ease in lingual motion. The authors did note a slight decrease in tongue strength from pretreatment to 1 month following treatment; they hypothesized that this minimal reduction was due to early side effects of treatment, including mucositis, pain, and soreness. The most significant finding of this study was the reported lack of relationship between tongue strength and residue in the oral cavity or pharynx; this finding was significant because of the contradiction from previous studies’ findings that lingual strength was a critical factor affecting pharyngeal residue and safety of swallowing. However, as later stated by Logemann et al., (2008), the lingual strength in the study was measured as an isolated task rather than in the context of swallowing, so results should be interpreted cautiously.

Summary and Need for Study

As a result of the difficulties that head and neck cancer patients experience following surgical resection of oral cavity structures and resulting treatments such as chemotherapy and radiation, assessment and treatment of dysphagia in this population
become complex and extensive. Due to the importance of lingual muscles on the safety of swallowing, research on this group of individuals is valuable; measuring and comparing lingual pressures in head and neck cancer patients against healthy adults can provide advantageous information for treatment plans and prognosis for these patients. Thus, this study was designed to answer the following research questions and hypotheses.

*Research Questions and Hypotheses*

Research Question 1: Do the mean anterior tongue pressures during saliva swallows in a healthy woman differ from the anterior tongue pressures during saliva swallows in an age-matched woman who is status post treatment for tongue cancer?

Null Hypothesis: The mean anterior tongue pressures during saliva swallows in a healthy woman will not differ from anterior tongue pressures during saliva swallows in an age-matched woman who is status post treatment for tongue cancer.

Research Question 2: Do the mean posterior tongue pressures during saliva swallows in a healthy woman differ from the posterior tongue pressures during saliva swallows in an age-matched woman who is status post treatment for tongue cancer?

Research Hypothesis: The mean posterior tongue pressures during saliva swallows in a healthy woman will be higher when compared to the posterior tongue pressures during saliva swallows in an age-matched woman who is status post treatment for tongue cancer.
CHAPTER 3

Methods

Participants

Two adult female participants were recruited to participate in this study. Participant one was 55 years old and served as a healthy control. She was ambulatory and in good health, and reported no reported history of pulmonary disease, neurological disease or injury, structural disorders, speech and language disorders, swallowing disorders, or voice disorders. Additionally, she did not wear dentures or have a history of palatal disorders.

Participant two was 52 years old and had a diagnosis of oral cancer, treated with an anterior partial glossectomy with free flap reconstruction and radiation treatment 1 year prior. She was recruited from a local clinic. Similar to participant one, she was ambulatory and in otherwise good health, and she reported no reported history of pulmonary disease, neurological disease or injury, speech and language disorders, swallowing disorders prior to the partial glossectomy, or voice disorders. Additionally, she did not wear dentures or have a history of palatal disorders.

Both participants underwent an oral motor examination (see Appendix A) to determine the physical status of their oral motor mechanism and ability to participate in the study. Participant one demonstrated no abnormal findings. Participant two demonstrated reduced lingual protrusion, retraction, lateralization, elevation, depression, tongue base-to-pharyngeal wall contact, protrusion against resistance. She also had restricted lingual coordination and decreased taste. She was determined eligible to participate in the disordered population portion of the study. Each participant was
consented to participate per University of Cincinnati IRB guidelines. Two types of consents are used depending on whether the individual is healthy or diagnosed with dysphagia due to a disease or disorder.

*Materials and Procedure*

The Swallowing Signals Lab Model 7120B (Kay Elemetrics, Lincoln Park, NJ) was used to obtain lingual pressure in both the control and experimental participants. The lingual pressure data was obtained using spineless three-bulb tongue arrays. The spineless arrays are affixed to the hard palate using stoma adhesive, a type of caulking material used to adhere the array to a moist area such as the inside of the oral cavity (in this case, the hard palate). The stoma adhesive allows the array to maintain its position within the mouth so that the array is stable for all bolus consistency introductions. Figure 1 shows a spineless three-bulb tongue array affixed to an individual’s hard palate at midline (see Figure 1).

*Figure 1. Spineless tongue bulb array affixed with stoma adhesive.*
**Protocol**

Following the oral mechanism examination, the spineless array was placed and affixed each participant’s mouth by the researcher, as described above. After the data was collected, the researcher made temporal (time), pressure amplitude (mm/Hg) measurements, and configuration tracings to record healthy data and/or track patient progress. Figure 2 shows an individual with the KayPENTAX Swallowing Signals Lab (Kay Elemetrics, Lincoln Park, NJ) measurement instruments in place.

![Individual with nasal cannula, spineless tongue bulb array, and acoustic signal instrumentation in place.](image)

*Figure 2.* Individual with nasal cannula, spineless tongue bulb array, and acoustic signal instrumentation in place.

Each participant was allowed up to five saliva and five 5 ml water swallows to become accustomed to the presence of the tongue bulb array. Following the adjustment period, the protocol began and each participant performed five saliva swallows, ten swallows of 5 mls (teaspoons) of room temperature water, and five swallows of 5 mls of applesauce/pudding (puree consistency) (only saliva swallow data was examined for the purpose of this study). The participants performed saliva swallows across two time periods so as to measure any differences in lingual pressure across time; peak lingual pressure at anterior and posterior tongue bulb positions were also measured for each
saliva swallow. Each participant was seated upright and instructed to breathe through the nose and swallow at a comfortable rate.

Data Collection

The researcher used the KayPENTAX Swallowing Signals Lab (Kay Elemetrics, Lincoln Park, NJ) tagging tool for each saliva swallow, at anterior and posterior tongue bulb positions, so that later analysis of the measurements could be performed. For example, the researcher tagged the saliva swallows accordingly: “Saliva Swallow 1,” “Saliva Swallow 2,” or in some instances “Dry Swallow 1,” “Dry Swallow 2,” and so on.

The researcher employed a case study design due to the limited number of healthy and head and neck cancer participants available for the study. The descriptive nature of this design allows one-to-one comparison to be performed between participant one and participant two. However, in-depth statistical analyses could not be performed in such a case study design.

Independent Variables: The independent variables in the study are the saliva swallows performed at time period 1 and time period 2 for participant one and two at two points in time.

Dependent Variables: The dependent variables in the study are the peak lingual pressure measurements at anterior and posterior lingual positions for participant one and two at two points in time.

Data Analysis

The researcher viewed each saliva swallow’s peak lingual pressure for both anterior and posterior bulbs on the array, at two points in time. The researcher used a mouse and keyboard to scroll through each saliva swallow to determine the precise peak
lingual pressure during the individual swallow (i.e., the highest number available during scrolling at the peak of each swallow). The peak pressures for all saliva swallows for both participants were then entered into an Excel database. Figures 3 and 4 show an example of a tagged saliva swallow and the waveform for lingual pressures as viewed on the Swallowing Signals Lab workstation (Kay Elemetrics, Lincoln Park, NJ).

Figure 3. Tagged saliva swallow (dry swallow).

Figure 4. Waveform as seen on the KayPENTAX Swallowing Signals Lab workstation.

The saliva swallow (dry swallow) shown in Figure 3 shows the lingual pressure elevation and reduction during this one swallow task; the peak pressure occurs at the
highest point during the swallow. Figure 4 shows several saliva swallows sequentially; the elevations, reductions, and peaks for each swallow can be seen on the waveform. The mean, range, and standard deviations for both participants’ saliva swallows, at anterior and posterior tongue bulb positions, and for both time periods were calculated.
CHAPTER 4

Results

The peak lingual pressures for the 55-year-old healthy female and the 52-year-old female head and neck cancer participant during saliva swallows were recorded in the Excel database. Ranges and means were then calculated across two time periods, taking into account anterior and posterior tongue bulb positions. The lingual pressures for the anterior tongue position for participant one range from 44-187 mmHg, whereas participant two’s lingual pressures for the anterior tongue position range from 10-38 mmHg. Lingual pressures for the posterior tongue position range from 209-451 mmHg for participant one, and 0-90 mmHg for participant two.

Table 1 (see below) shows the means, ranges, and standard deviations for both participants’ peak lingual pressures during saliva swallows, at both tongue positions, across the two time periods. For participant one, mean anterior lingual pressures were 106.4 and 108.4 (time period 1 and 2), while the mean posterior lingual pressures were 323 and 373.6 (time period 1 and 2). Participant two’s mean anterior lingual pressures were 30.4 and 11.6 (time period 1 and 2), and her mean posterior lingual pressures were 58.6 and 66.2 (time period 1 and 2). Figure 5 (see below) shows the mean peak lingual pressures for both participants. Tables 2 and 3 (see below) show the lingual pressures (in mmHg) during all saliva swallows for both participants, for anterior and posterior tongue positions, across the two time periods.
Table 1. *Average Peak Lingual Pressure (in mmHg) Standard Deviations, and Range during Saliva Swallows*

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<td>373.6</td>
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<td>373.6</td>
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**Standard Deviations**

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**Range**

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*Figure 5. Average Peak Lingual Pressure (in mmHg) during Saliva Swallows*
Table 2. Participant One Peak Lingual Pressure Measurements during Saliva Swallow, Across Two Time Periods and Anterior/Posterior Tongue Bulb Positions (in mmHg)

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Table 3. Participant Two Peak Lingual Pressure Measurements during Saliva Swallow, Across Two Time Periods and Anterior/Posterior Tongue Bulb Positions (in mmHg)

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</table>
CHAPTER 5

Discussion

Dysphagia is a complex neurophysiologic process, even in healthy adults who have not experienced injury or disease. When disease does affect an individual, especially in the case of head and neck cancer, swallowing becomes an even more complex process due to the changes in anatomy and musculature within the oral cavity. Because many head and neck cancer patients also undergo treatment such as chemotherapy or radiation therapy following surgical resection of tumors, the effects on swallowing can multiply significantly. With loss of lingual muscle tissue, the tongue’s performance during swallowing tasks is decreased simply due to lack of tissue needed to form and propel a bolus safely. Tissue fibrosis and xerostomia as a result of radiation treatment further complicate the oral musculature’s ability to manipulate materials and initiate a safe swallow. As a result of the difficulties that head and neck cancer patients experience following surgical resection of oral cavity structures and resulting treatments such as chemotherapy and radiation, assessment and treatment of dysphagia in this population become multifaceted and extensive. Due to the importance of lingual muscles on the safety of swallowing, research on this group of individuals is valuable; measuring and comparing lingual pressures in head and neck cancer patients against healthy adults can provide advantageous information for treatment plans and prognosis for these patients. Thus, this study was designed to determine the differences in lingual pressures during saliva (dry) swallows between a healthy adult and an adult status post head and neck cancer.
Anterior Peak Lingual Pressure

The peak lingual pressures for participant one and participant two are similar to the peak lingual pressures of healthy adults and adults who have undergone head and neck cancer treatment (Nicosia et al., 2000; Ball et al., 2006). Of interest in participant one’s peak lingual pressures are the two relatively low measurements at the anterior bulb position upon initiation of the first saliva swallow in each time period. At this point in the protocol, the participant had been allowed up to five practice saliva swallows and five practice liquid swallows to adjust to the tongue bulb array in her mouth; she had also performed five maximum lingual pressure measurements prior to beginning the saliva swallows in the protocol. However, the maximum lingual pressure measurements were performed without a required subsequent swallow; perhaps the participant was still becoming accustomed to the tongue bulb array in the mouth at the time of beginning the saliva swallows. Speculation still exists, though, as to the low measurement at the anterior position for time period 2, as the participant had performed a total of 20 swallows for time period 1, in addition to 10 practice swallows before beginning the overall protocol. Examination of other participants’ measurements in future studies may show a pattern by which additional explanation can be made.

Posterior Peak Lingual Pressure

Of note, also, are participant two’s anterior tongue bulb position measurements during time period 2. These measurements are quite low as compared to the anterior position during time period 1. These measurements suggest that the participant was experiencing lingual fatigue anteriorly during the swallowing tasks, perhaps which can be
attributed to the additional exertion necessary to overcome the anterior lingual anatomical deficits as a result of her partial glossectomy.

*General Findings*

The variations are clear in the reduced lingual pressures for participant two as compared to participant one. As can be expected, the posterior tongue pressures were greater than the anterior tongue positions in both participants, as the posterior tongue’s role is to propel the bolus posteriorly into the esophagus with significant force against the posterior pharyngeal wall; this assists in steering the bolus away from the larynx and trachea, eliminating the risk for penetration and aspiration. Despite participant two’s reduction in lingual pressure measurements in comparison to participant one, the trend for the posterior lingual pressure to be greater than the anterior tongue pressure still remained in this participant’s physiology of swallow.

Similar to the findings discovered by Pauloski (1998), Lazarus et al. (2000), and Lazarus (2006), this study revealed that the participant who underwent a partial glossectomy and received radiation treatment post-operatively demonstrated decreases in lingual pressures at both anterior and posterior tongue positions when compared to the lingual pressures of the age- and gender-matched healthy participant. The descriptive nature of this study prevented the statistical analysis that could determine the results’ true significance and correlations; however, evaluating the results clinically affords the opportunity to conclude that variations in the lingual pressures between participant one and participant two are, in fact, noteworthy. The Null Hypothesis stating that the mean anterior tongue pressures during saliva swallows in a healthy woman will not demonstrate differences from the anterior tongue pressures during saliva swallows in an
age-matched woman who is status post treatment for tongue cancer was, thus, rejected. The Research Hypothesis stated that the mean posterior tongue pressures during saliva swallows in a healthy woman will be increased when compared to the posterior tongue pressures during saliva swallows in an age-matched woman who is status post treatment for tongue cancer; this hypothesis was supported.

Participant two in this study underwent surgery approximately 1 year ago and has since received radiation therapy. As discussed above, surgical intervention negatively affects swallowing physiology simply due to the removal of pertinent structures involved in coordination of a safe swallow. In addition to surgery, radiation treatment compounds the effects that can be seen in these patients, resulting in often severe dysphagia. Pauloski and Logemann (2000) conducted a longitudinal study of six patients who had undergone surgical and radiation intervention; their results suggested that the reduction in pharyngeal driving force was the result of radiation-induced fibrosis of the patients’ oropharyngeal musculature, similar to the results found in this study. Such fibrosis led to decreases in the tongue’s ability to retract, decreased bulging in the posterior pharynx, and reduced duration in tongue base-to-pharyngeal wall contact.

Implications

The implications of such contrast in the lingual pressures between participant one and participant two are numerous. With reduced anterior lingual pressure, participant two can experience increased oral transit times with difficulty forming and propelling the bolus posteriorly, as well as reduced bolus control in the oral cavity and buccal spaces. Reduced posterior lingual pressures result in decreased tongue base-to-pharyngeal wall contact, reduced constriction in the hypopharynx, and increased risk of premature
spillage of the bolus over the base of the tongue, resulting in vallecular and pyriform sinus pooling, with increased risk of penetration and/or aspiration of the bolus (Furia et al., 2000). Taking all of these changes of anatomy and physiology into consideration, the clinician’s role in treating head and neck cancer patients for dysphagia is vital and relies upon cooperation among professionals to ensure the patient’s safety during deglutition, as well as his/her quality of life throughout the disease and treatment process.

Future Research

This study was a pilot study for future research to be conducted with additional participants in each category, which would provide a basis for experimental statistics to be performed and effect size to be calculated. The small number of participants and the descriptive nature of this study prevented the inclusion of statistical analysis and experimental comparison. The collection of head and neck cancer participants was limited due to study approval and ease of finding participants in the stages of recovery necessary for acceptance of foods orally. Many head and neck cancer patients are limited on their oral intake following surgery, and the presentation of puree and liquid boluses would not have been possible, or ethical, with all patients. Finding participants in the appropriate stages of recovery, following surgery and pre- and post-chemotherapy and/or radiation, was difficult due to the specific deadlines these patients are on for their treatment regimen.

Additional research could expand on the study, taking into account other bolus conditions and peak lingual pressure measurements, comparing them not only across healthy adult age groups, but also to the head and neck cancer population, considering
also participants’ gender and the variations in lingual pressures between men and women. Such a study has the potential to affect treatment plans for head and neck cancer patients based on the differences in lingual pressures and areas of strength/weakness. Future studies could also narrow the focus of the head and neck cancer population to reduce the variables this study included (such as focusing on partial glossectomy with mandibulectomy versus partial glossectomy without mandibulectomy, etc.) to further increase the accuracy of differences among even the head and neck cancer patients.

Finally, research could be performed to determine the variations in measurements between the use of spined arrays and spineless arrays. Because of the difficulties maintaining positioning within the mouth using the spined arrays, results could be somewhat variable if participants used both types of arrays during a study. Determining the most reliable and valid type of array for research purposes would benefit the overall database of healthy data to be gathered.

Gathering such data on healthy adults and adults with head and neck cancer can benefit speech language pathologists and researchers by providing normative data against which to compare their patients and track their progress. A database readily available for such comparisons could be shared and expanded upon to include various populations of individuals. Such research and data would be prized within the field and certainly relied upon by clinicians for its relevance when treating patients.
References


Sample ORAL MOTOR/CLINICAL/PHYSICAL SWALLOWING EXAMINATION

Name (initials):
Date:
Examiner:

Background/History:

Current Feeding Status: __________________ Respiratory Status: __________________

Behavioral Observations: ________________ Medications: _______________________

Current weight: ________________ Desired weight: _______________________

General appearance of the oral cavity and dentition:

Motor Evaluation: (present-WNL/absent/impaired)

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Depress
Tongue base/PPW
Protrude w/resist.
Velum/pharynx
Elevation/mobility

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**Vocal Function CN 10 RLN/SLN**
- Sustained /ah/ ____________ seconds
- Sustained /i/ ____________ seconds
- Pitch control ____________ (SLN eb)
- Voluntary cough ____________ (strong/weak/dysphonic)
- Reactive Cough ____________ (CN 10 SLN ib)
- Vocal Quality ______________

**Rapid Alternating Speech/Artic**
**Dry Swallow**
- On command (yes/no)
- Laryngeal elevation (yes/no/diminished)
- Secretions

**Bolus Swallow**
- Swallow Reflex (present/absent/delayed)
- Laryngeal elevation
- Sequential swallows
- Vocal quality
- Signs of aspiration

**Communication/Cognition:**

**General Impressions:**

**Recommendations:**