

# Tongue Strength and Exercise in Healthy Individuals and in Head and Neck Cancer Patients

Cathy Lazarus, Ph.D., BRS-S<sup>1</sup>

## ABSTRACT

The tongue plays a critical role in bolus propulsion through the oral cavity and pharynx. This manuscript reviews the types of lingual impairment and overall oropharyngeal swallowing impairment present after treatment for head and neck cancer; specifically, surgery and primary chemoradiotherapy. Oral tongue impairment in surgically treated patients can include reduced range of motion, reduced control, and reduced ability to manipulate, seal, and propel a bolus into the pharynx. Tongue base impairment can result in reduced bolus clearance through the pharynx, resulting in pharyngeal residue and aspiration. The biologic effects of radiotherapy are described, with tissue fibrosis being a primary contributor to development of oropharyngeal swallow disorders. In patients treated with primary chemoradiotherapy, lingual strength has been found to be reduced, as has oral and pharyngeal structural movement during the swallow. The effects of skeletal muscle strengthening programs on muscle physiology are discussed, as are the effects of tongue strengthening exercise programs on tongue strength and swallowing. Future research needs are addressed.

**KEYWORDS:** Tongue strength, head and neck cancer, swallowing

**Learning Outcomes:** As a result of this activity, the reader will be able to identify how tongue function and swallowing are impaired in the treated head and neck cancer population.

Treatment for head and neck cancer can result in swallowing problems affecting both oral and pharyngeal phase swallow functioning.

Treatment can include surgery, with or without radiotherapy, or organ preservation treatment, typically chemoradiotherapy. Both surgery and

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organ preservation treatments can result in deficits of tongue function that can negatively affect oral and pharyngeal phase swallow function.

## EFFECTS OF SURGERY ON TONGUE FUNCTION AND SWALLOWING

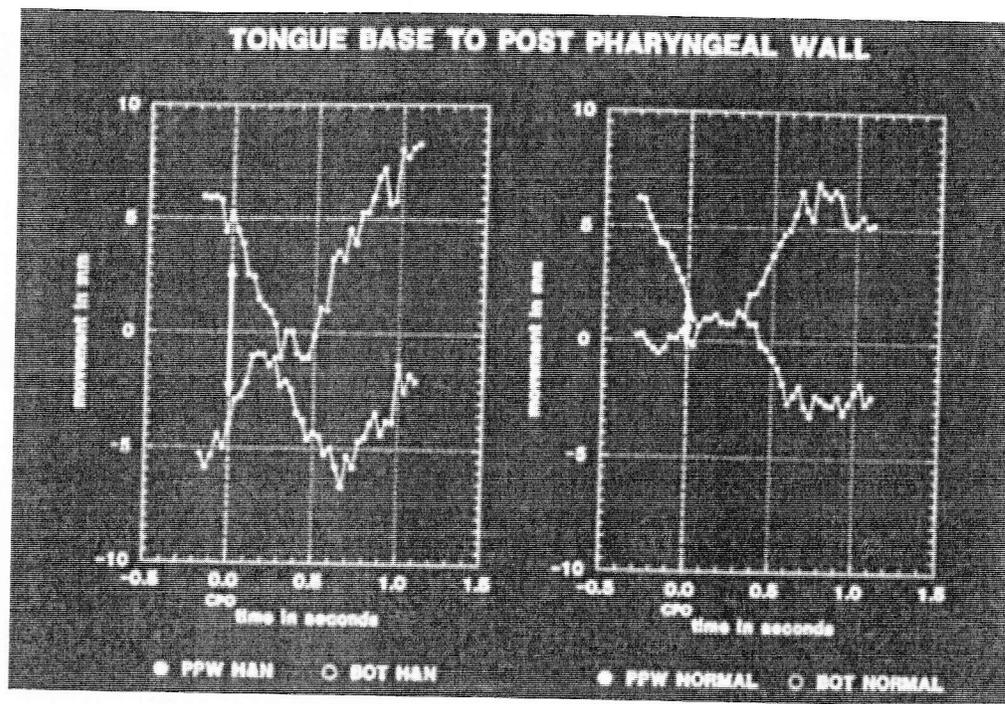
The tongue plays a major role in the propulsion of the bolus through the oral cavity into the pharynx and through the pharynx. The tongue prepares the bolus for propulsion into the pharynx, providing the containment, shaping, control, lateralization, retrieval of, and sealing of the bolus against the palate in preparation for propulsion into the pharynx.<sup>1,2</sup> The tongue acts as a two-pump system during swallowing, with the oral component providing the driving force to propel the bolus through the oral cavity into the pharynx and the tongue base providing the driving force to propel the bolus through the pharynx.<sup>3-6</sup>

Surgical resection of oral and oropharyngeal cancer can result in deficits in tongue function that can affect both the oral and pharyngeal phases of swallowing. Patients having undergone oral and oropharyngeal cancer resections demonstrate difficulty with oral tongue range of motion, strength, control, bolus manipulation, and propulsion into the pharynx, resulting in prolonged oral transit times, oral residue, and increased number of swallows per bolus.<sup>7-14</sup> In addition, pharyngeal phase swallow impairment in this same population can include reduced tongue base range of motion, delayed triggering of the pharyngeal motor response, reduced pharyngeal contraction, reduced hyolaryngeal motion, reduced airway entrance closure, and reduced opening within the upper esophageal sphincter region, resulting in pharyngeal residue and aspiration.<sup>8,10-15</sup> Timing of the muscular components of the pharyngeal motor response can be delayed, sluggish, and discoordinated.<sup>10</sup> Postoperative radiotherapy can have a negative effect on swallow functioning and can result in worsened performance.<sup>14</sup> Pauloski, Rademaker, and Colangelo<sup>15</sup> found poorer swallow functioning in a group of oral cancer patients treated with surgery and postoperative radiotherapy as compared with a similar group of surgically

treated patients without postoperative radiotherapy. Specifically, irradiated patients were found to have longer oral transit times, lower oropharyngeal swallow efficiency, increased pharyngeal residue, and reduced cricopharyngeal opening duration.

## EFFECTS OF ORGAN PRESERVATION TREATMENT ON TONGUE FUNCTION AND SWALLOWING

Organ preservation treatment protocols of radiotherapy with or without chemotherapy for head and neck cancer can result in cure rates similar to those seen following surgery with or without postoperative radiotherapy.<sup>16-18</sup> However, these protocols also can result in reduced quality of life, particularly as evidenced by swallowing problems after treatment.<sup>19-23</sup> Oral and pharyngeal phase swallowing disorders have been observed in head and neck cancer patients treated with organ-preserving protocols of chemoradiotherapy.<sup>11,24-31</sup> Oral phase impairment has been observed, with reduced range of lingual motion, reduced lingual strength, impaired bolus formation, impaired bolus transport through the oral cavity, prolonged oral transit times, and increased oral residue percentages.<sup>11,24,25</sup> Pharyngeal phase swallowing disorders include impaired tongue base posterior movement, impaired velopharyngeal closure, delayed triggering of the pharyngeal swallow, reduced pharyngeal contraction, reduced hyoid and laryngeal motion, reduced laryngeal vestibule and glottic closure, and reduced opening of the upper esophageal sphincter, resulting in impaired bolus clearance and aspiration.<sup>24-34</sup> The extent, rate, timing, and coordination of pharyngeal structural movement is often impaired, resulting in reduced bolus clearance through the pharynx and aspiration, the last of which is often silent.<sup>11,24,25,28,29,32-36</sup> Lazarus and colleagues<sup>29</sup> examined swallowing in a group of nine head and neck cancer patients with mixed tumor sites treated with organ preservation chemoradiotherapy and in a group of age- and gender-matched healthy controls. A biomechanical analysis of swallows with videofluoroscopy revealed slower, more sluggish movement of pharyngeal structures during the pharyngeal



**Figure 1** Example of reduced extent of tongue base and pharyngeal wall motion during the swallow in a head and neck cancer patient treated with chemoradiotherapy and a healthy age- and gender-matched control. (Taken from Lazarus, et al. *Laryngoscope* 1996;106:1167-1166.)

motor response as compared with healthy controls. In addition, patients exhibited reduced extent of structural movement (i.e., incomplete tongue base to pharyngeal wall contact, reduced laryngeal elevation, reduced hyoid motion) as compared with controls. Figure 1 shows incomplete tongue base-to-pharyngeal wall contact during the swallow in a patient treated with chemoradiotherapy as compared with an age- and gender-matched healthy control.

The effects of radiotherapy often result in persistence or worsening of swallow function over time (i.e., several years),<sup>31-34,37,38</sup> and are likely caused by the late radiation changes that occur with reduced vascular supply to the muscles and by eventual tissue fibrosis.<sup>39-42</sup> Fibrosis within the oral and pharyngeal musculature is believed to be the primary cause of oral and pharyngeal phase swallowing impairment.<sup>11,30,32,34,37,38</sup>

The effects of radiotherapy on tissue can also include impaired neural transmission, impaired muscle contraction, fewer muscle

fibers, and reduced fiber size, as well as the replacement of muscle with connective and fibrotic tissue as a result of a reduction in blood supply to the muscle.<sup>40-46</sup> Studies examining the effects of radiotherapy on muscle strength have found decrements in strength with radiotherapy.<sup>47,48</sup> These studies, however, have focused on the limbs. Muscle wasting and loss of movement have also been observed as early and late complications following radiotherapy to skeletal muscle.<sup>47</sup> Interestingly, Watkin and colleagues<sup>42</sup> found that the use of lingual gestures improves blood flow to the tongue in healthy individuals and in patients treated with chemoradiotherapy. Their data argue for lingual exercise programs to potentially prevent lingual fibrosis and swallowing impairment.

A recent study by Lazarus<sup>49</sup> examined tongue strength in a group of 12 head and neck cancer patients with mixed tumor sites treated with primary radiotherapy with or without chemotherapy. Tumor sites included tongue base or tonsil ( $n=5$ ), nasopharynx

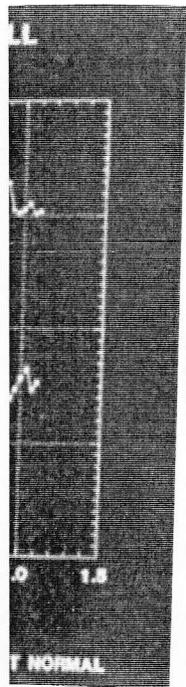
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Swallow in a head-down position. (Taken from Lazarus et al.)

( $n=4$ ), hypopharynx ( $n=2$ ), and larynx ( $n=1$ ). Time since completion of radiotherapy was 1 month to 15 years, with a mean of 72 months in these patients. All patients underwent assessment of tongue strength and videofluoroscopic swallow assessment. Results revealed impairment of tongue base posterior motion for swallowing, as observed radiographically, in all patients. In addition, all patients demonstrated reductions in tongue strength as compared with normative data in healthy individuals.<sup>50</sup> Clearly, even for those patients with tumors not originating in the tongue, all patients demonstrated decrements in tongue strength and tongue base function for swallowing. Radiation treatment volume included the oropharynx as a result of neck disease in all of these patients, which likely resulted in lingual tissue fibrosis and reduced function for swallowing. Similar radiation treatment volume was seen in a group of 13 oral and oropharyngeal cancer patients treated with primary chemoradiotherapy<sup>11</sup> (Table 1). These patients demonstrated deficits in tongue strength as compared with age- and gender-matched healthy control subjects. These patients also demonstrated impairment in oral and pharyngeal phase swallow functioning following treatment. Oral phase disorders include reduced ability to propel the bolus into the pharynx, resulting in prolonged oral transit times and

oral residue, and reduced tongue strength, resulting in tongue and palate coating after the swallow. Pharyngeal phase motility disorders included reduced tongue base posterior motion, reduced laryngeal elevation, and reduced laryngeal vestibule closure, all of which resulted in reduced bolus clearance through the pharynx and pharyngeal residue, some of which residue was aspirated after the swallow in these patients. These oropharyngeal swallow disorders are likely caused by the fibrotic effects of radiotherapy. Tongue strength in these patients correlated with oropharyngeal swallow efficiency,<sup>51</sup> a global measure of swallow efficiency that takes into account the speed of the swallow, the approximate percentage swallowed, and aspiration before or during the swallow. Greater tongue strength correlated with higher oropharyngeal swallow efficiency measures. In addition, tongue endurance correlated with percentage oral residue in these patients, with greater endurance correlating with less oral residue.

### TONGUE STRENGTHENING EXERCISE AND SWALLOWING

#### Tongue Strength and Swallowing in Abnormal Populations

Tongue strength is clearly important for bolus transport and clearance through the oral cavity and the pharynx. Indeed, increased muscular activity is required to propel firmer food boluses through the oral cavity in healthy individuals.<sup>52</sup> Lazarus et al<sup>11</sup> found that tongue strength correlates with temporal measures of oropharyngeal swallowing, including oral and pharyngeal transit times and percentage of oral residue. Tongue strength has been found to be a good predictor of oral phase swallowing impairment, including bolus manipulation and clearance.<sup>53</sup> Kays et al<sup>54</sup> found tongue strength impairment to correlate with maximal isometric pressures, maximum swallow pressures, and impairment of swallow function, as measured by Penetration/Aspiration Scale scores<sup>55</sup> in a group of stroke patients. They further found that the Penetration/Aspiration Scales differentiated aspects of the occurrence of airway penetration among normal swallows, stroke patients, and

**Table 1 Radiation Treatment Volume for 13 Patients Treated with Primary Chemoradiotherapy for Oral and Oropharyngeal Tumors**

Organ in Radiation	Field Number of Patients
Parotid gland	13
Submandibular gland	13
Oral tongue	13
Tongue base	12
Soft palate	12
Oropharynx	12
Hypopharynx	12
Supraglottic larynx	5
Entire larynx	6

Reproduced from Lazarus CL, Logemann JA, Pauloski BR, Rademaker AW, Larson CR, Mittal BB, Pierce M. Swallowing and tongue function following treatment for oral and oropharyngeal cancer. *Journal of Speech-Language and Hearing Research* 2000;43:1011-1023.

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cancer patients subsequent to head and neck cancer treatment.<sup>56</sup>

groups as compared with the control no-exercise group.

### **Tongue Strengthening Programs: Healthy Individuals**

Muscle strengthening programs can include isometric, isotonic, and isokinetic exercise. During an isometric muscle contraction, the muscle fibers maintain a constant length throughout the entire contraction. The exercise is typically performed against an immovable surface. Isotonic exercise differs from isometric exercise in that there is movement of a joint during the muscle contraction. A classic example of an isotonic exercise is weight training with free weights. The muscle shortens and lengthens as the weight is lifted throughout the range of motion. Isokinetic exercise uses machines that control the speed of muscle contraction within the range of motion. These three types of muscle strengthening programs have been found to improve muscle strength in skeletal (i.e., limb) muscles in healthy and in neurologically impaired individuals.<sup>57-67</sup> In addition, muscle strengthening programs have resulted in muscle hypertrophy, increased neural activation, and increases in the number of muscle fibers.<sup>57-59,61-70</sup>

Studies have examined the effects of tongue strengthening programs on tongue strength in healthy populations, including healthy young and elderly populations.<sup>71,72</sup> Studies have found significant improvement in maximal tongue strength following isometric lingual exercise programs in these healthy populations. Lazarus and colleagues<sup>71</sup> examined two types of tongue strengthening exercise programs using the Iowa Oral Performance Instrument<sup>73,74</sup> and tongue depressors as compared with a control (no-exercise) group of similarly aged healthy individuals. The exercise programs included lingual resistance against the Iowa Oral Performance Instrument or tongue depressor five times daily, 5 days per week for 6 weeks. These authors found no difference in tongue strength between the two exercise groups (i.e., Iowa Oral Performance Instrument and tongue depressors) but found a significant difference in tongue strength for the combined exercise

### **Tongue Strengthening Programs: Abnormal Populations**

Until recently, few studies have examined tongue exercise programs in the abnormal population. A case study examining the effects of exercise on tongue strength in a single surgically treated oral cancer patient found that exercise improved tongue strength.<sup>75</sup> Kays and colleagues<sup>54</sup> studied the effects of an 8-week tongue strengthening exercise program on tongue strength and swallowing in cerebrovascular accident (CVA) patients. These authors found significantly improved maximal isometric tongue pressures, maximal swallowing pressures, improved Penetration/Aspiration Scale<sup>55</sup> scores, and improved swallow quality of life.<sup>76</sup> A National Institutes of Health/National Institute on Deafness and Other Communication Disorders randomized clinical trial currently being conducted by Lazarus and colleagues at the New York University School of Medicine and Bellevue Hospital Center is examining the effects of two types of swallowing treatment protocols, one of which includes a tongue strengthening exercise protocol for oral and oropharyngeal cancer patients treated with chemoradiotherapy. This study will provide information on the effects of tongue strengthening exercises on the maximal tongue strength and swallow functioning in this population. Results of this study may provide evidence as to potential benefit to other populations, including surgically treated oral cancer patients, those treated with primary chemoradiotherapy for other head and neck tumor sites, and patients with neurologic impairment. In addition to examining the benefit of tongue strengthening exercise protocols in other abnormal populations, future studies should examine dosage, frequency, and length of treatment on tongue strength and swallow function. In addition, future studies are needed to determine timing of exercise programs in relation to cancer treatment, particularly in the treated head and neck cancer patient, as there may be a limited temporal window in which treatment will have a beneficial effect.

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