AMERICAN ACADEMY OF OTOLARYNGOLOGY– HEAD AND NECK SURGERY FOUNDATION

Otolaryngology–
Head and Neck Surgery
144(1) 21–28

DOI: 10.1177/0194599810390906
http://otojournal.org
SAGE

Impact of a Laryngectomy and Surgical Closure Technique on Swallow Biomechanics and Dysphagia Severity

Julia Maclean, MSc[1], Michal Szczesniak, PhD[2], Susan Cotton, PhD[3], Ian Cook, MD[2], and Alison Perry, PhD[4]

Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Abstract

Objective. The incidence of self-reported dysphagia following a laryngectomy is high (72%). The impact, if any, of a surgical closure technique on swallowing biomechanics and dysphagia severity is not known. To date, there is no recommended standard procedure for pharyngeal reconstruction during laryngectomy surgery. The aim of this study was to determine how laryngectomy surgery alters swallowing biomechanics, pharyngeal peak deglutitive pressure, and hypopharyngeal intrabolus pressures and whether these changes in pressure correlate with specific surgical closure after total laryngectomy or with dysphagia severity.

Study Design. Combined videoradiography and manometry was used to measure peak mid-pharyngeal, tongue, and intrabolus pressures; anatomical derangements; postswallow residue; and pharyngeal dimensions.

Setting. Radiology Department, St George Hospital, Sydney, Australia.

Subjects. Twenty-four patients following total laryngectomy surgery and age-matched control data.

Results. When compared to controls, peak mid-pharyngeal pressures were significantly reduced in laryngectomy patients ($P < .001$). Hypopharyngeal intrabolus pressures were significantly higher in patients when compared to controls ($P < .001$). Patients who had undergone mucosa-and-muscle pharyngeal reconstruction had higher peak mid-pharyngeal pressures compared to those who had mucosa-alone closure ($P \leq .04$). Combined mucosa-and-muscle closure was also associated with reduced postswallow residue, indicative of a more efficient swallow.

Conclusion. Following laryngectomy surgery, pharyngeal propulsive contractile forces are impaired, and there is increased resistance to bolus flow across the pharyngoesophageal segment. These adverse biomechanical effects can be influenced by surgical techniques, providing surgeons with evidence for optimum pharyngeal closure following a laryngectomy to improve swallowing outcomes.

Keywords

dysphagia, swallowing, laryngectomy, manometry, pharyngeal

Received August 2, 2010; revised August 3, 2010; accepted October 20, 2010.

Dysphagia is a somewhat underrecognized but common sequela of laryngectomy surgery, with 72% of patients reporting long-term swallowing problems.[1] Following a laryngectomy, the transit of the bolus through the pharynx is altered, and there is some evidence suggesting that there is increased pharyngeal resistance secondary to the altered anatomy.[2] These anatomical changes result in decreased swallowing efficiency, evidenced by impaired pharyngeal clearance of the swallowed bolus.

The type of the surgical reconstruction may affect the intraluminal pressures developed during the swallow or, more specifically, the efficiency of bolus propulsion and clearance from the pharynx.[2] Surgical techniques for pharyngeal reconstruction vary widely and depend not only on the site and extent of the tumor but also, to a large degree and in a somewhat arbitrary fashion, on each surgeon's preferences.[3] For example, a recent survey of Australian head and neck (H&N) surgeons demonstrated marked variation in the *levels of closure* (some preferring mucosa-alone closure, others combining mucosa and muscle for closure) and the *orientation of closure* (vertical closure, transverse closure, or a combination).[3] Following the pharyngeal reconstruction, a diverticulum,[4-6] a pseudoepiglottis,[2,6] cricopharyngeal dysfunction,[5]

[1]Cancer Care Centre, St George Hospital, Sydney, Australia
[2]Department of Gastroenterology, St George Hospital, Sydney, and The University of New South Wales, Sydney, Australia
[3]Orygen Youth Health Research Centre, Centre for Youth Mental Health, University of Melbourne, Melbourne, Australia
[4]School of Human Communication Sciences, La Trobe University, Melbourne, Melbourne, Australia

Corresponding Author:
Julia Maclean, Cancer Care Centre, St George Hospital, Short St, Kogarah NSW 2217, Australia
Email: Julia.Maclean@sesiahs.health.nsw.gov.au

and/or a stricture have been reported.[4] These additional anatomical derangements may further adversely affect bolus flow through the reconstructed pharynx, increasing the likelihood of a severe dysphagia.

To date, the major measurement tools used to evaluate the pharyngeal swallow following a laryngectomy are (cine- or video-) radiography, either alone[4-7] or combined with intraluminal manometry (manofluorography or videomanometry).[2] Videomanometry has proven to be an extremely useful technique to evaluate pharyngeal dynamics and biomechanics because it provides not only information on wall motion, anatomical features, and bolus transport and clearance but also information on the propulsive and resistive forces affecting bolus transport.[8] Peak mid-pharyngeal intraluminal pressure provides an indication of the forces generated by the pharyngeal constrictor muscles during swallowing. However, hypopharyngeal intrabolus pressure varies as a function of the forces exerted on the bolus as well as any from resistance to bolus flow as it moves through the pharyngoesophageal junction. Intrabolus pressure thereby provides crucial information about the compliance of the reconstructed upper esophageal sphincter (UES)—the major component of which is the cricopharyngeus.[9-11]

To our knowledge, only 1 study has used videomanometry to study patients following a laryngectomy.[2] In that study, pressure was measured from the tongue base to the hypopharynx, but at that time (24 years ago), the importance of measuring intrabolus pressure was not fully appreciated.

Hence, although it appears likely that, postlaryngectomy, there is an increased resistance to bolus flow, the effect, if any, of the type of reconstruction on the biomechanics of the swallow and upon swallow efficiency or symptom severity remains unknown.

The aim of this study, using combined videoradiography and solid-state manometry, was to determine whether a laryngectomy alters pharyngeal peak deglutitive and intrabolus pressures and whether such changes, if they occur, correlate with the technique(s) of surgical closure or with dysphagia severity. Specifically, we hypothesized the following: (1) peak pharyngeal contraction pressures are reduced and hypopharyngeal intrabolus pressure is increased following a laryngectomy, (2) these pressure changes correlate with both dysphagia severity and with surgical closure technique, and (3) surgical closure technique is an important determinant of the likelihood of developing postlaryngectomy dysphagia.

Methods

Patients and Controls

Twenty-six patients who had had a total laryngectomy for squamous cell carcinoma (SCC) of the larynx were recruited from St George Hospital (n = 14), St Vincent's Hospital Sydney (n = 6), and the Laryngectomee Association of New South Wales (NSW) (n = 6). Institutional ethics committee approval was obtained from La Trobe University's Faculty of Health Sciences' Human Ethics Committee, Victoria, and the South Eastern Sydney and Illawarra Area Health Service's Human Research Ethics Committee, and all participants gave written informed consent. No patient had a history of a neurological disorder (eg, a stroke or Parkinson disease), had previous dysphagia, or had been previously treated for another H&N cancer. Eighteen of these patients had undergone adjuvant treatment(s). Age-matched control videomanometric data for liquid swallows were obtained from a cohort of healthy individuals whose normative data had been derived previously at our laboratory.[10]

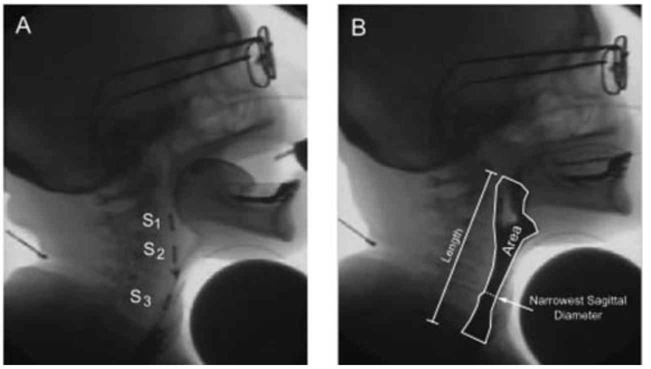

Figure 1. (A) Position of manometry catheter in lateral projection. (B) Methodology used to obtain measures of pharyngeal dimensions.

Assessment Tools

Australian Therapy Outcome Measures. Swallowing-related activity (limitation) was documented using the swallowing scale of the Australian Therapy Outcome Measures (AusTOMs). The AusTOMs, based on the World Health Organization's (WHO's) International Classification of Functioning, Disability and Health have been validated[12,13] previously and were used with patients who had H&N cancer.[14] Participants rated themselves using a 5-point scale from 0 (profound activity limitation) to 5 (no activity limitation),[15] with a score of less than 5 indicating self-reported dysphagia.

Videomanometry. Videomanometric recordings were achieved as previously detailed.[16,17] Briefly, a solid-state catheter (CT/S3 6010416; Gaeltec, Isle of Skye, Scotland), incorporating 3 radiopaque sensors spaced 2 cm proximally and 3 cm distally, was positioned transnasally with the proximal sensor positioned at the base of the tongue, aligned with the angle of the ramus of the mandible (**Figure 1**).

Participants were first seated upright in the lateral plane with their head in a neutral position. Simultaneous pharyngeal videofluoroscopy and manometry data were recorded and digitized on a single workstation (KayPENTAX, Lincoln Park, New Jersey). Fluoroscopic images were obtained with a 12-in Philips image intensifier (MultiDiagnost Eleva; Philips, Andover, Massachusetts). At study commencement, 2 metallic scale markers, spaced 3 cm apart, were placed briefly in the field of view and imaged in the midline above the patient's head to permit correction for any magnification factor in the sagittal and anteroposterior (AP) planes.

Once seated in lateral projection, participants swallowed 3, 5, 10, and 20 mL of high-density barium sulfate suspension (Liquibar, MCI Forrest, West Footscray, Victoria, Australia), 5 mL fruit puree mixed with high-density barium, and 2 × 2-cm bread slices soaked in barium sulfate. Single swallows of 3, 5, 10, and 20 mL were then recorded in AP projection.

Data Capture

Demographic/surgical information. Medical records were sourced for demographic information (ie, age, sex, and whether any adjuvant treatment had been performed), and operative records were examined for details of the total laryngectomy surgery (levels of pharyngeal closure—mucosa and muscle vs mucosa alone; the direction of pharyngeal closure—vertical, transverse, or a combination "T/Y"; and whether a myotomy had been performed).[18]

Videomanometry. Radiographically determined anatomical features were attributed to each patient by consensus between 2 experienced observers (JM and MS). Pharyngeal diverticulum and/or a pseudoepiglottis were noted for each participant where present. Pharyngeal dimensions were measured from still images in both sagittal and AP projections while the patient swallowed the 10-mL bolus—that is, when the pharynx was maximally distended and barium contrast filled the entire pharyngeal cavity. All dimensions were adjusted for any magnification using the control radio-opaque marker for distances, aided by ImageJ software (version 1.41; National Institutes of Health, Bethesda, Maryland). Measurements were converted from pixels to millimeters. Both the mean and the narrowest diameters within the entire pharynx (in both sagittal and AP projections) were determined for each patient, and the level of the cervical vertebra at which the narrowing occurred was noted. Mean diameter was calculated from the area of the bolus-filled pharyngeal cavity with the length of the pharyngeal segment as the denominator.

As previously described,[17] hypopharyngeal intrabolus pressure was determined at the distal sensor, as the pressure at the time point midway between the arrival of the bolus head at this sensor and the onset of the major pressure upstroke, which is coincident with the arrival of the bolus tail at that sensor. The maximum peak hypopharyngeal and base-of-tongue pressures were also documented at the distal and proximal sensors, respectively.

Statistical Analyses

Inferences regarding potential effects of surgery on manometric and radiographic measurements were made by comparing patients with controls, using 1-sample *t* tests. Pressure differences between patients with and without dysphagia were evaluated using unpaired *t* tests. Fisher's exact test was used to compare proportions of patients with dysphagia according to type of surgical closure (mucosa alone vs muscle/mucosa closure and vertical vs T/Y closure). Finally, assigning closure type as the independent variable (mucosa alone vs mucosa and muscle; vertical vs combination T/Y), unpaired *t* tests were used to make inferences about potential closure-related differences in pharyngeal diameter and in pressures. For all analyses, an alpha value of 0.05 was considered significant, and a very low probability was reported as <.001.

Results

Patient Characteristics

Of 26 laryngectomy patients recruited to this study, 24 completed the full assessment protocol (1 could not tolerate intubation, and the manometry catheter malfunctioned with another). There were 19 men and 5 women with an average mean (SD) age of 65 (9.2) (**Table 1**).

Twelve patients (50%) had self-reported dysphagia, and the remainder had *no* swallowing difficulties (on the swallowing scale of the AusTOMs). Most patients had undergone adjuvant treatment (n = 18), with all receiving radiotherapy and 3 receiving chemoradiation. Seven patients received their adjuvant treatment prior to their total laryngectomy surgery. Most patients (n = 15) were studied within 5 years of having undergone their total laryngectomy.

The method of pharyngeal closure at surgery varied across the cohort; 20 patients underwent a "mucosa-and-muscle" closure, and 4 patients had their pharynx closed with "mucosa alone." A T- or Y-shaped closure was most commonly used (n = 12), with vertical closure (n = 8) being the next most common (**Table 1**). One patient underwent a transverse closure. Three operative reports did not contain specific information regarding the direction of pharyngeal closure, with comments such as "the pharynx was closed in the routine fashion." A myotomy had been performed on 14 of 24 patients. Some operative reports gave details of the length of the myotomy performed or stated that a "long" myotomy was conducted; however, the precise anatomical extent of the myotomy could not be obtained from any operative report. In 8 patients (30%), a myotomy was not performed, and in 2 patients, the reports did not specify whether a myotomy had been performed.

Videomanometry

Pharyngeal pressures. Laryngectomy patients had significantly diminished peak mid-pharyngeal pressures, compared to controls of similar age (laboratory normal ranges), when swallowing both 5- and 10-mL boluses ($P < .001$; **Figure 2**). A bolus volume-dependent increase in intrabolus pressure was recorded in both laryngectomy patients and age-matched controls. Across the bolus volumes, intrabolus pressure was significantly greater in patients when compared to control data from our laboratory ($P < .001$; **Figure 3**). Four patients who had mucosa-alone closure had significantly lower peak pharyngeal pressure than the patients who had muscle and mucosa closure for 3-mL, 5-mL, and puree boluses ($P \leq .05$; **Figure 4A**). The pharyngeal closure technique (mucosa alone vs mucosa and muscle) had no effect on intrabolus pressure (**Figure 4B**). Peak mid-pharyngeal pressures and intrabolus pressures did not vary according to whether patients had undergone a myotomy at the time of their laryngectomy surgery. The 4 patients

Table 1. Demographic and Surgical Features of Total Laryngectomy Cohort

Age	Sex	Myotomy	Direction of Closure	Levels of Closure	Adjuvant Treatment	Salvage Surgery	Dysphagia
62	M	+	Vertical	MM	XRT	+	+
72	M	+	Vertical	MA	No adjuvant	–	–
78	M	+	Vertical	MA	XRT	–	+
58	F	–	Transverse	MM	XRT	+	–
61	M	+	T/Y	MM	No adjuvant	–	–
51	M	+	Vertical	MM	CRT	–	–
78	F	+	T/Y	MM	No adjuvant	–	+
70	M	–	T/Y	MM	No adjuvant	–	–
68	M	+	T/Y	MM	XRT	+	–
68	M	+	Vertical	MA	CRT	–	–
73	M	–	T/Y	MM	XRT	–	+
82	M	–	T/Y	MM	XRT	+	+
50	M	–	T/Y	MM	No adjuvant	–	+
66	F	NR	Vertical	MM	XRT	–	+
63	M	+	Missing	MM	XRT	+	+
57	M	–	T/Y	MM	XRT	+	–
46	M	NR	T/Y	MM	XRT	–	+
63	M	+	Vertical	MA	No adjuvant	–	–
60	M	–	T/Y	MM	CRT	–	–
68	M	+	Vertical	MM	XRT	–	+
61	F	+	T/Y	MM	XRT	–	+
60	M	+	Missing	NR	XRT	–	+
74	M	–	Missing	MM	XRT	–	–
73	F	–	T/Y	MM	XRT	+	–

Abbreviations: CRT, chemoradiation; MA, mucosa-alone; MM, mucosa-and-muscle closure; NR, feature not recorded; XRT, radiotherapy. +/– denotes presence or absence of reported feature.

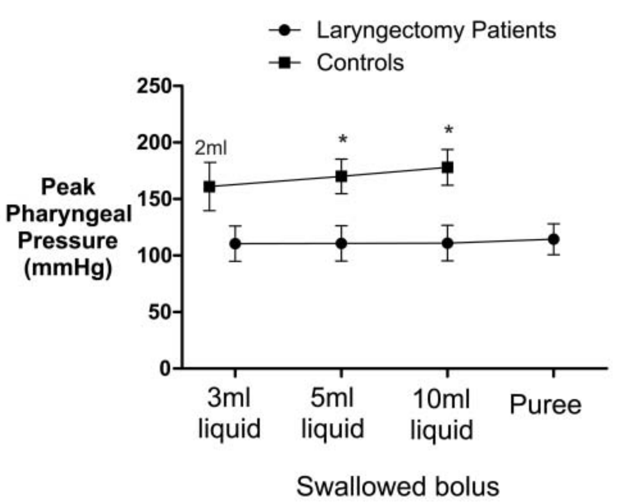

Figure 2. Average ± SE peak pharyngeal pressures for a range of swallowed bolus volumes. Peak pharyngeal pressures noted to be significantly lower ($P < .001$) in laryngectomy patients.

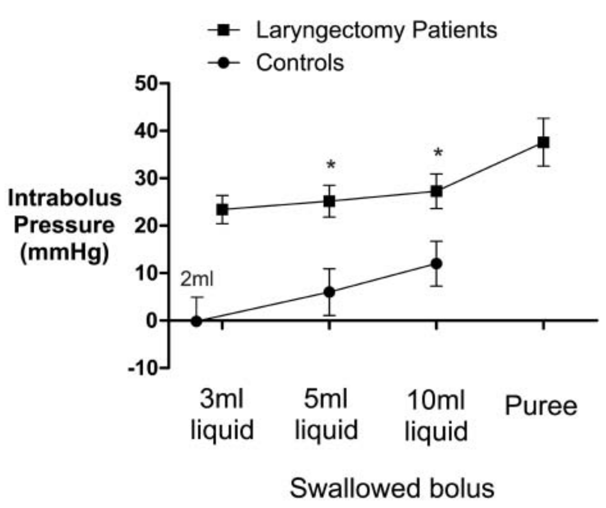

Figure 3. Average ± SE intrabolus pressures for a range of swallowed bolus volumes. Intrabolus pressure noted to be significantly higher ($P < .001$) in laryngectomy patients.

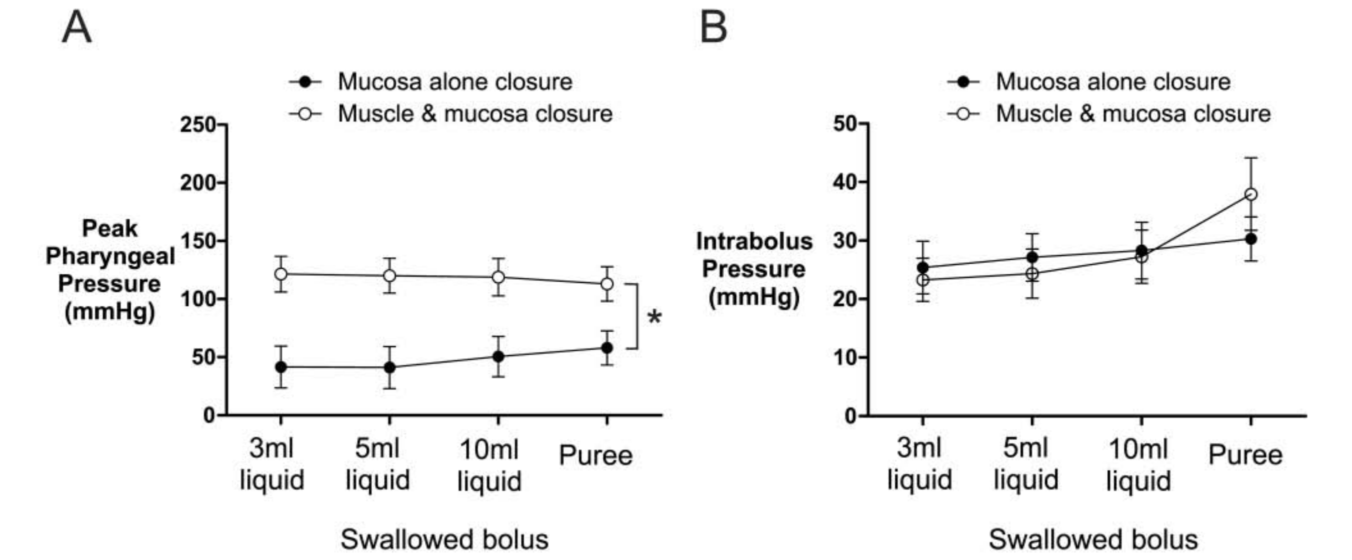

Figure 4. Average ± SE peak mid-pharyngeal and intrabolus pressures stratified by pharyngeal closure technique. (A) Laryngectomy patients with mucosa-alone closure have significantly ($P = .04$) lower peak mid-pharyngeal pressure than patients with muscle and mucosa closure. (B) Intrabolus pressure was not related to pharyngeal closure technique.

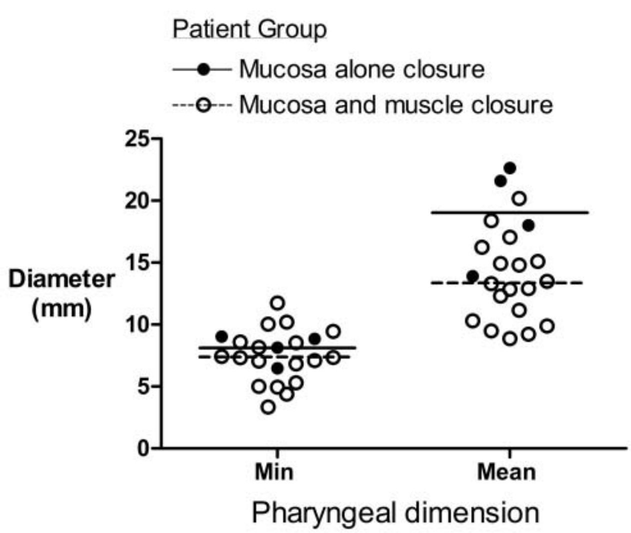

Figure 5. Smallest and mean pharyngeal diameters during swallowing (10 mL) with a significantly increased ($P < .001$) mean pharyngeal diameter in patients with a mucosa-alone closure.

who had mucosa-alone pharyngeal closure had a significantly greater mean pharyngeal diameter in the sagittal projection than did the patients who underwent a mucosa-and-muscle closure ($P < .001$; **Figure 5**). When comparing peak mid-pharyngeal pressures, there were no significant differences evident between those patients with and without self-reported dysphagia (**Table 2**).

Anatomical derangements and swallowing efficiency across laryngectomy cohort. Eleven patients had a pseudoepiglottis present, and 10 patients had a diverticulum in which post-swallow material collected. When the pharynx was at its greatest distension with a 10-mL bolus, the mean (SD) pharyngeal diameters were 13.4 (3.5) mm in the AP projection and 14.4 (4.0) mm in the sagittal projection. At that time, the narrowest diameter of the pharynx in the AP projection was, on average, 7.2 (2.3) mm and 7.5 (2.1) mm in the sagittal projection. The narrowest portion of the reconstructed pharynx occurred most frequently at the level of fifth to seventh cervical vertebrae.

Most patients (n = 22) had difficulty tolerating a 20-mL bolus, swallowing it as 2 or 3 piecemeal boluses, whereas 18 patients required more than 1 swallow to clear a bread bolus, and 6 patients were unable to successfully swallow any of the bread boluses. Hence, data from the 20-mL liquid bolus and bread swallows were excluded from further analyses.

Postswallow pharyngeal residue was observed in most patients for all consistencies and volumes. The 3-mL liquid bolus was best tolerated, with 21% of participants not having any postswallow residue. Postswallow bolus residue correlated with increased bolus volume and with increased viscosity across the cohort ($P < .001$; **Figure 6**).

Self-reported dysphagia and surgical closure. Most patients who self-reported dysphagia on the AusTOMs (n = 12) had moderate activity limitation (n = 10, score = 3). They were able to manage an oral diet but required modification to the texture of the diet (eg, eating puree diet only). Two reported moderate to severe activity limitation (score = 2, requiring some alternative/supplemental nutrition). Laryngectomees with self-reported dysphagia had a reduced minimum pharyngeal diameter compared to those without self-reported dysphagia ($P \leq .05$). Having had a myotomy during laryngectomy surgery was not associated with self-reported dysphagia. There was also no significant relationship between the direction or levels of closure and the presence of self-reported dysphagia.

Table 2. Tongue, Peak Mid-Pharyngeal, and Intrabolus Pressures for 3-mL, 5-mL, 10-mL, and Puree Boluses in Patients With and Without Dysphagia

		Tongue		Peak MPP		IBP	
Bolus	Patient Group	Mean (SD)	*P* Value	Mean (SD)	*P* Value	Mean (SD)	*P* Value
3 mL	Dysphagia	118.05 (52.20)	.20	137.06 (91.45)	.03*	23.99 (5.60)	.42
	No dysphagia	104.99 (23.98)		88.49 (47.64)		22.87 (2.76)	
5 mL	Dysphagia	111.83 (24.02)	.10	134.11 (90.07)	.56	28.08 (21.67)	.67
	No dysphagia	111.49 (25.27)		1.22 (51.92)		22.52 (8.46)	
10 mL	Dysphagia	121.97 (48.24)	.97	119.10 (91.64)	.17	30.64 (23.20)	.18
	No dysphagia	114.54 (35.28)		103.64 (59.20)		24.18 (9.92)	
Puree	Dysphagia	133.28 (43.51)	.64	124.81 (26.12)	.03*	45.54 (31.55)	.11
	No dysphagia	116.44 (30.06)		105.69 (46.48)		33.43 (12.48)	

Abbreviations: IBP, intrabolus pressure; MPP, mid-pharyngeal pressure. *P* value derived from independent sample *t* tests.
*Although significant at $P < .05$, when using Bonferroni corrections for 3 planned comparisons within each bolus, results are not significant at the $P < .02$ level.

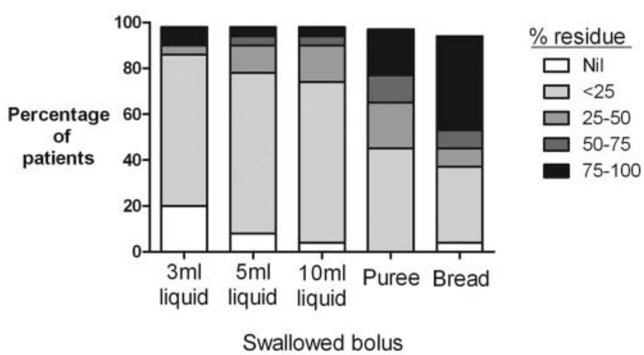

Figure 6. Pharyngeal residue postswallow: shading indicates the amount of residue as a percentage of the swallowed bolus. Pharyngeal residue increases significantly ($P < .001$) as size and viscosity of the bolus increase.

Discussion

The major findings from this study were that laryngectomy was associated with reduced peak mid-pharyngeal pressures during swallowing and with increased hypopharyngeal intrabolus pressure when compared to healthy age-matched controls. Postoperative peak mid-pharyngeal pressures were significantly influenced by surgical closure technique during pharyngeal reconstruction. Patients with a mucosa-and-muscle closure appear to have superior swallowing function, with peak mid-pharyngeal pressures remaining closer to normative measures and fewer diverticula when compared to those patients who had only mucosa-alone closure. Using muscle in the pharyngeal reconstruction may result in a more tonic closure, thereby improving the propulsive forces of the pharynx.

In contrast, intrabolus pressure, which is a measure of resistance to flow across the pharyngoesophageal segment, was not influenced by closure technique. Across the cohort, intrabolus pressure was significantly increased, regardless of the type of surgical closure employed, consistent with increased restriction to bolus flow through the reconstructed pharyngoesophageal segment. Measurement of the pharyngeal diameter provided further evidence to support pharyngeal restriction, with the minimal diameter observed on fluoroscopy in laryngectomees being significantly reduced (7.2 mm and 7.5 mm in sagittal and AP projections, respectively) when compared with the maximal dimensions of UES during transsphincteric flow in aged controls (10.6 mm and 15.7 mm in sagittal and AP projections, respectively).[19]

Restriction to bolus flow and increased intrabolus pressure may result in increased deglutitive pulsion forces on the pharyngeal walls. They may also be related to the formation of frequently observed diverticula in the reconstructed pharynx of laryngectomees. Increased resistance to pharyngeal bolus flow coupled with diminished peak pharyngeal pressures may also account for a large amount of postswallow pharyngeal residue observed in these patients. In this cohort, amount of residue increased as the bolus size and viscosity increased, and the majority of patients were unable to swallow a 20-mL liquid bolus or a bread bolus as a single swallow.

Peak mid-pharyngeal and intrabolus pressures did not differ between patients who did and those who did not report symptoms of dysphagia. Furthermore, dysphagia was not recognized or reported in many patients despite evidence of significant pharyngeal residue. This may be due to a number of reasons. First, there may be changes to the sensation of the pharynx as a result of sectioning the superior laryngeal nerve and/or recurrent laryngeal nerve.[4] Second, these patients often expect some "trade-off" in levels of functioning after such significant cancer surgery, and they gradually adapt to these changes.[1] Third, there is limited research using instrumental tools, so the incidence of dysphagia is really unknown. Last, these patients may not wish to alert clinicians about their swallowing difficulty because of their anxiety (ie, that this symptom indicates a recurrence of their cancer).[20]

In this cohort, the different types of surgical closure employed were unrelated to self-report of dysphagia. There were no significant differences between the direction or levels of pharyngeal closure and self-report of dysphagia. Interestingly, the prevalence of dysphagia was not lower in patients for whom a myotomy had been performed and documented.

As many of the operative reports did not contain detailed information regarding the length or position of the myotomy, we could not stratify patients by the *type* of myotomy performed. Some surgeons have suggested that a short myotomy of the UES and inferior constrictors should be routinely undertaken at the time of total laryngectomy,[18] whereas others have recommended a long myotomy (including all of the pharyngeal constrictor muscles from the base of the tongue to the esophageal inlet).[18] The decision about whether to perform a myotomy is made at the time of pharyngeal reconstruction, and it may have been selectively performed if or when the pharyngeal lumen was narrow, skewing the results.

Problems following total laryngectomy surgery include a narrowing of the reconstructed pharynx, the presence of a stricture, and a pharyngeal pouch (diverticulum and pseudoepiglottis). A diverticulum occurs in 47% of people after a total laryngectomy,[5] and the presence of a pseudoepiglottis has also been frequently documented.[6] Ten (42%) of this study's cohort had a diverticulum, and 11 (46%) presented with a pseudoepiglottis that was significant enough to leave a residue of postswallow material. All 4 patients with a mucosa-alone closure had a diverticulum and/or a pseudoepiglottis. The presence of these anatomical complications did not correlate with self-reports of dysphagia. Laryngectomees with dysphagia, however, had a reduced minimum pharyngeal diameter compared with those without dysphagia. The reasons for why such anatomical problems result in dysphagia are not clear. In 1 study of laryngectomees, there was no established correlation between the size of the neopharynx and postoperative swallowing function.[21] However, the reconstructed pharynx will have its size and shape determined by the amount of remaining pharyngeal tissue available following removal of the larynx.[5] We have shown that both levels (mucosa alone/mucosa and muscle) and direction (vertical/transverse/T or Y) of pharyngeal closure influence the size and shape of the reconstructed pharynx. Patients with a mucosa-alone closure had a significantly greater mean pharyngeal diameter, with a lack of the tonicity that was evident in those who underwent a mucosa-and-muscle closure. Caution is required in interpreting this result, as only 4 of these patients had a mucosa-alone closure. Despite our larger study cohort, because of the presence of several surgical variables and confounding factors (ie, the use of chemotherapy and radiation), larger sample sizes in each of the surgical groups would be optimal before drawing more definitive conclusions. However, the sizable effects on pharyngeal pressures demonstrated in this relatively small cohort do suggest that surgical closure technique is an important determinant of postoperative swallow biomechanics. Larger studies would be useful to help determine whether such changes translate into dysphagia severity. To aid with future studies, it is important to improve the level of detail in operative reports by specifying the features of the closure, the site and length of myotomy, and the reconstructive technique(s) undertaken.

Conclusion

Total laryngectomy is life-altering surgery, and survivorship is challenging because of the negative changes to speech and swallowing. Swallowing is permanently altered, with pharyngeal pressures being significantly different from normative measures. Better awareness by surgeons of the relationship between their surgery/reconstruction and eventual function (eg, speech and swallowing) can only enhance the outcomes for these patients.

Acknowledgment

This article is part of a wider research study that is generously funded through the Laryngectomee Association of NSW as part of Julia Maclean's PhD studies at La Trobe University, Melbourne, Victoria. The Dysphagia Swallowing Workstation was obtained using a technology enhancement grant through the Cancer Institute of NSW.

Author Contributions

Julia Maclean, substantive contribution to concept and design, acquisition of data, analysis and interpretation of data, drafting and revising the article; **Michal Szczesniak**, assistance with concept and design, acquisition of data, analysis and interpretation of data, drafting and revising the article; **Susan Cotton**, assistance with analysis and interpretation of data, drafting and revising the article; **Ian Cook**, assistance with concept and design, interpretation of data, drafting and revising the article, final approval of the version to be published; **Alison Perry**, assistance with concept and design, interpretation of data, drafting and revising the article, final approval of the version to be published.

Disclosures

Sponsorships: Laryngectomee Association of NSW.

Funding source: Julia Maclean was provided with a PhD stipend to complete research.

References

1. Maclean J, Cotton S, Perry A. Post-laryngectomy—it's hard to swallow: an Australian study of prevalence and self-reports of swallowing function after undergoing a total laryngectomy. *Dysphagia*. 2009;24:172-179.
2. McConnell FS, Mendelsohn MS, Logemann JA. Examination of swallowing after total laryngectomy using manofluorography. *Head Neck Surg*. 1986;9:3-12.
3. Maclean J, Cotton S, Perry A. Variation in surgical methods used for total laryngectomy in Australia. *J Laryngol Otol*. 2008;122:728-732.
4. Balfe DM. Dysphagia after laryngeal surgery: radiologic assessment. *Dysphagia*. 1990;5:20-34.
5. Muller-Miny H, Eisele DW, Jones B. Dynamic radiographic imaging following total laryngectomy. *Head Neck*. 1993;15: 342-347.
6. Nayar RC, Sharma VP, Arora MML. A study of the pharynx after laryngectomy. *J Laryngol Otol*. 1984;98:807-810.
7. Davis RK, Vincent, ME, Shapshay SM, Strong MS. The anatomy and complications of 'T' versus vertical closure of the hypopharynx after laryngectomy. *Laryngoscope*. 1982;92:16-20.
8. Cook IJ, Gabb M, Panagopoulos V, et al. Pharyngeal (Zenker's) diverticulum is a disorder of upper esophageal sphincter opening. *Gastroenterology*. 1992;103:1229-1235.
9. Bulow M, Olsson R, Ekberg O. Supraglottic swallow, effortful swallow, and chin tuck did not alter hypopharyngeal intrabolus

pressure in patients with pharyngeal dysfunction. *Dysphagia*. 2002;17:197-201.
10. Shaw DW, Cook IJ, Jamieson GG, Gabb M, Simula ME, Dent J. Influence of surgery on deglutitive upper oesophageal sphincter mechanics in Zenker's diverticulum. *Gut*. 1996;38:806-811.
11. Williams RB, Wallace KL, Ali GN, Cook IJ. Biomechanics of failed deglutitive upper esophageal sphincter relaxation in patients with neurogenic dysphagia. *Am J Physiol*. 2002; 283:G16-G26.
12. Perry A, Morris M, Unsworth C, et al. Therapy outcome measures for allied health practitioners in Australia: the AusTOMs. *Int J Quality Health Care*. 2004;16:285-291.
13. Unsworth CA, Duckett SJ, Duncombe D, Perry A, Skeat J, Taylor N. Validity of the AusTOM scales: a comparison of the AusTOMs and EuroQol-5D. *Health Quality Life Outcomes*. 2004;2:1-12.
14. Frowen J, Cotton S, Corry J, Perry A. The impact of demographics, tumor characteristics and treatment factors on swallowing function after chemo-radiotherapy for head and neck cancer. *Head Neck*. 2010;32:513-528.
15. Perry A, Skeat J. *AusTOMs for Speech Pathology*. Melbourne, Australia: La Trobe University; 2004.
16. Cook IJ, Weltman MD, Wallace K, et al. Influence of aging on oral-pharyngeal bolus transit and clearance during swallowing: a scintigraphic study. *Am J Physiol*. 1994;266:G972-G977.
17. Cook IJ, Dodds WJ, Dantas RO, et al. Opening mechanisms of the human upper esoophageal sphincter. *Am J Physiol*. 1989; 257:G748-G759.
18. Hamaker RC, Cheesman AD. Surgical management of pharyngeal constrictor muscle hypertonicity. In: Blom ED, Singer MI, Hamaker RC, eds. *Tracheoesophageal Voice Restoration Following Total Laryngectomy*. San Diego, CA: Singular Publishing Group; 1998:33-39.
19. Shaw DW, Cook IJ, Gabb M, et al. Influence of normal aging on oral-pharyngeal and upper esophageal sphincter function during swallowing. *Am J Physiol*. 1995;268:G389-G396.
20. Llewellyn C, Weinman J, McGurk M, Humphris G. Can we predict which head and neck cancer survivors develop fears of recurrence? *J Psychosom Res*. 2008;65:525-532.
21. Hui Y, Wei WI, Yuen PW, Lam HK, Ho WK. Primary closure of pharyngeal remnant after total laryngectomy and partial pharyngectomy: how much residual mucosa is sufficient? *Laryngoscope*. 1996;106:490-494.