

Pharyngeal Swallowing Disorders

Selection for and Outcome After Myotomy

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Objective

To develop selection criteria based on the mechanical properties of pharyngoesophageal swallowing that indicate when patients with pharyngeal dysphagia will benefit from a myotomy.

Summary Background Data

The pathophysiology of pharyngoesophageal swallowing disorders is complex. The disorder is of interest to several medical specialists (gastroenterologists, otorhinolaryngologists, general and thoracic surgeons), which contributes to confusion about the entity. The management is compounded because it is most frequently seen in the elderly, is often associated with generalized neuromuscular disease, and occurs with a high prevalence of concomitant disease. The selection of patients for myotomy is difficult and of major importance to the quality of life of the affected patients.

Method

One hundred seven patients without a Zenker diverticulum but with pharyngeal dysphagia underwent a detailed

manometric assessment of the upper esophageal sphincter (UES). Cricopharyngeal opening was identified by the presence of a subatmospheric pressure drop before bolus arrival. Impaired pharyngoesophageal segment compliance resulting in a resistance to pharyngoesophageal flow was determined by measuring the intrabolus pressure generated by a 5-ml liquid bolus.

Results

Thirty-one of 107 patients underwent a myotomy (29%). Both impaired sphincter opening and increased intrabolus pressure predicted a good outcome.

Conclusion

Myotomy is beneficial in patients with pharyngeal swallowing disorders and manometric evidence of defective sphincter opening and increased intrabolus pressure.

Pharyngeal swallowing is a mechanical process. It requires the thyrohyoid muscle groups to elevate the larynx, the glossopharyngeal musculature to propel the bolus, the cricopharyngeus to relax, and the cervical esophageal muscle to be compliant.¹⁻⁶ This equates mechanically to three primary forces:

- A traction force (F_{traction}) from the contractions of the thyrohyoid muscles, resulting in the anterior-superior

movement of the hyoid bone and in turn elevation of the larynx

- A muscle force (F_{muscle}) from the active and passive tone within the inferior constrictor, cricopharyngeal, and cervical esophageal muscles that resists sphincter opening
- a bolus force (F_{bolus}) generated by the glossopharyngeal muscles that propel the bolus into the pharyngoesophageal segment.

For opening of the UES to occur, the following must be true:

$$F_{\text{traction}} - F_{\text{muscle}} + F_{\text{bolus}} \geq 0 \text{ (atmospheric pressure), or}$$
$$F_{\text{traction}} + F_{\text{bolus}} \geq F_{\text{muscle}}$$

Manometry can measure the forces involved in the transfer of a bolus from the hypopharynx into the esophagus and the resistance to flow imposed by noncompliant cricopharyngeal

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Table 1. UNDERLYING DISEASE ASSOCIATED WITH PHARYNGEAL DYSPHAGIA

Cause	Total Number	Number Undergoing Myotomy	Excellent to Good Outcome (#)
None	66	14	14
Cerebrovascular accident	20	8	5
Postradiation Injury	6	1	0
Postmeningioma resections	3	3	2
Parkinsonism	3	1	0
Inclusion body myositis	1	—	—
Dystrophica myotonia	1	—	—
Diphtheria	1	1	0
Polymyalgia rheumatica	1	—	—
Amyotrophic lateral sclerosis	1	1	1
Richard olszewski syndrome	1	1	1
Spinocerebellar degeneration	1	—	—
Oculopharyngeal muscular dystrophy	1	1	1
Multiple sclerosis	1	—	—

ryngeal and cervical esophageal muscles. These measurements provide insight into the mechanical deficiencies of the various steps in the swallowing process and a logical basis for therapy. Surgeons can substantially alter F_{muscle} and possibly F_{traction} . The aim of this study was to identify manometric markers of pharyngeal swallowing that would serve as a guide to the selection of patients who would benefit from a cricopharyngoesophageal myotomy.

POPULATION AND METHODS

The study population consisted of 143 consecutive patients referred to the swallow clinic between 1991 and 1997 with symptoms suggestive of a pharyngeal swallowing disorder. Thirty-six patients with a Zenker diverticulum were excluded. The remaining 107 patients consisted of 50 women and 57 men with a median age of 72 years (range 25 to 98). All patients were evaluated with a video esophagram and detailed manometry of the pharyngoesophageal segment. A standardized questionnaire completed by all the patients was used for symptom evaluation.

An underlying disease was not identifiable in 66 patients (Table 1). Fifteen patients had an underlying neuromuscular abnormality, and in 20 the swallowing difficulty was related to a cerebrovascular accident. A history of radiation injury to the pharynx was given by six patients.

A myotomy was offered to 46 patients who had severe symptoms with associated radiographic findings and motility evidence of outflow resistance. Thirty-one patients (17 women, 14 men) subsequently underwent a myotomy. The median age of the patients was 75 years (range 36 to 86). The remaining 61 patients were not offered surgery because of a combination of minor symptoms or lack of corroborating clinical, radiographic, and motility evidence of severe pharyngeal dysfunction. The postsurgical clinical outcome was graded as excellent (complete relief of all swallowing

symptoms), good (minor symptoms that persisted but did not require therapy), fair (minor symptoms that persisted and required therapy), or poor (presurgical symptom persisted or became worse). The median postsurgical follow-up was 12 months (range 2 to 48).

Video Esophagram

Videotaped sequences of the pharyngeal swallow process were made at 30 frames per second in a 10-inch mode using E-Z-HD barium. Anteroposterior and lateral projections of the oropharynx and upper esophagus were obtained. The impression of the cricopharyngeus was expressed as the percentage reduction in diameter of the distended pharyngoesophageal segment; a reduction of more than 50% of the luminal diameter was considered significant.

Manometry of the Pharyngoesophageal Segment

Manometry was performed after an overnight fast using an eight-channel water-perfused open-tipped polyvinyl catheter. The catheter was 0.9 m long and had an outer diameter of 4.8 mm; there were eight sideholes or pressure ports, each 0.8 mm in diameter. The most distal port was 10 cm from the end of the catheter; seven additional ports, located at 1-cm intervals, were oriented radially around the circumference of the catheter. The sampling frequency was 128 Hz. The recordings were digitized and analyzed on a computer. All pressure measurements were referenced to atmospheric pressure (B_0).

Procedure

The catheter was placed transnasally into the cervical esophagus, and the patient was placed in the supine position. A stepwise 1-cm station pull-through of the UES was

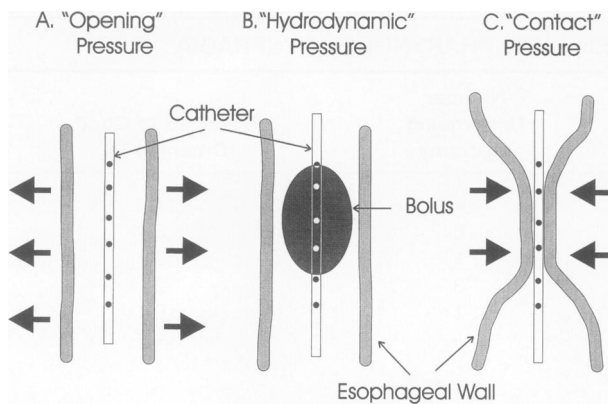


Figure 1. The manometry catheter during the three different physical conditions of the UES. Arrows indicate the direction of movement of the esophageal walls relative to the catheter. (A) The esophageal walls are distracted away from the catheter. During this phase, a falling pressure is recorded. (B) A bolus surrounds the pressure transducer on its passage through the pharyngoesophageal segment. During this phase, the pressure reflects the intrabolus pressure. (C) The esophageal or pharyngeal muscles contract and compress the catheter. During this phase of the swallow, a rising pressure is recorded.

performed. The resting sphincter length and pressure were measured from the pull-through record. The distal border of the UES was identified by a sustained rise in pressure above the esophageal baseline pressure. This rise was usually dramatic and obvious, on the order of at least 5 to 10 mmHg. The proximal border of the UES was identified by the return of sphincter pressure to B_0 . The resting pressure of the UES was measured as the mean pressure above B_0 during the pull-through. The proximal extent of the UES was crucial for determining the upward extent of the surgical myotomy.

The response of the pharyngoesophageal segment to swallowing was assessed using 10 swallows of 0, 5, 10, and 15 ml of water. To evaluate the distal portion of the segment, the first two sideholes were placed in the pharynx and the third sidehole was placed in or just proximal to the upper border of the UES. The remaining sideholes spanned the entire length of the UES and a small portion of the cervical esophagus. To analyze the proximal portion of the segment, the first four or five sideholes were placed in the pharyngeal segment, with the remaining sideholes straddling the UES.

Evaluation

The water-perfused manometry catheter can be used to measure pressure associated with three different physical conditions of the UES: cavity or opening pressure, hydrodynamic or intrabolus pressure, and contact or closing pressure (Fig. 1).

The mechanics of pharyngeal swallowing consist of a closed, an opening, an open, and finally a reclosing of the UES. The pressure sequence during a swallow is from a closing pressure to an opening pressure to a hydrodynamic pressure and finally back to a closing pressure. The

cavity or opening pressure reflects the pressure within the UES caused by the walls being pulled open (see Fig. 1A). During this phase, the walls of the pharyngoesophageal segment are no longer in contact with the catheter, and air fills the space. After the UES is opened, the bolus flows into the pharyngoesophageal segment, producing a hydrodynamic or intrabolus pressure. This pressure reflects the forces applied on the bolus as it passes through the UES and into the cervical esophagus (see Fig. 1B). The pharyngeal stripping wave closely follows the tail of the bolus, and as the pharyngeal and cricopharyngeal muscles squeeze down on the catheter, a contact or closing pressure occurs (see Fig. 1C).

The characteristic feature of the pressure tracing in the proximal pharyngoesophageal segment is that before the swallow, the catheter lies freely in the hypopharynx, exposed to atmospheric pressure. After the swallow is completed, the pressure tracing returns to atmospheric pressure (Fig. 2). The onset of a swallow (T_a) is identified by a rise in pressure more than 2 mmHg above B_0 . For dry swallows, this is the onset of the pharyngeal contraction (stripping) wave. For wet swallows, the onset is the movement of the bolus into the pharyngoesophageal segment; this is reflected by the hydrodynamic pressure within the bolus, or intrabolus pressure. A second steeper slope (T_b) occurs as the tail of the bolus passes the pressure port ahead of the pharyngeal stripping wave. The peak of this slope is the closing pressure of the pharyngeal wall on the pressure port and is the highest amplitude attained during a pharyngeal contraction (T_c). This is followed by a decline back to the resting pressure (t_d).

By comparing the pressure profile of the dry swallow with that of the wet swallows, it was easy to distinguish the intrabolus pressure. This is important because movement of the pharyngoesophageal segment over the catheter or the abutment of the tongue against the catheter often causes a sharp upward rise in pressure. This can be confused easily

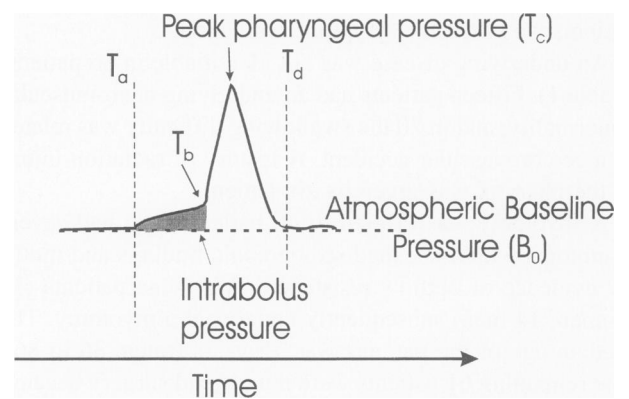


Figure 2. A typical pharyngeal pressure tracing. T_a = arrival of the bolus head. T_b = the bolus tail. T_c = the peak pressure of the pharyngeal stripping wave. T_d = completion of the pharyngeal pressure wave. B_0 = baseline atmospheric pressure.

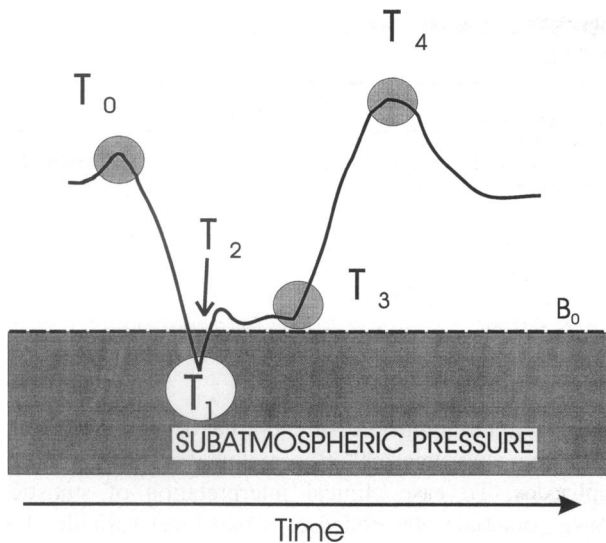


Figure 3. A typical UES pressure tracing, illustrating the distal pharyngoesophageal segment. T_0 = beginning of the swallow. T_1 = complete opening of the sphincter. With complete opening, the pressure is subatmospheric. T_2 = transition from a subatmospheric to a supraatmospheric pressure as the head of the bolus flows into the sphincter. T_3 = bolus tail ahead of the pharyngeal stripping wave. T_4 = peak pressure after luminal closure by the pharyngeal stripping wave. B_0 = baseline atmospheric pressure.

with the intrabolus pressure, but a comparison with the dry swallow will help to identify this artifact.

The pharyngeal stripping or clearing wave can be assessed by noting the interval between successive peak pharyngeal pressures recorded by different channels. The total duration of the pharyngeal event can be measured by noting the time interval between T_a and T_d .

The cricopharyngeal muscle or UES is closed at rest. At the onset of a swallow, the port in the proximal UES exhibits a rise in pressure, reflecting the upward motion of the tonically contracted sphincter on the manometry catheter (T_0) (Fig. 3). When this occurs, pressure ports in the more distal sphincter may exhibit an immediate drop in pressure, consistent with the port slipping caudally out of the sphincter into the esophagus as the larynx elevates. After this rise in pressure in the more proximal portion of the sphincter, a decline in pressure is observed with the relaxation of the sphincter. As the traction forces begin to dom-

inate, the rate of the pressure drop increases and a “check mark” or kink in the pressure tracing may be generated.⁷⁻¹¹ This is because the traction forces overcome the muscular forces, causing the sphincter walls to separate with the creation of a gap. The pressure becomes subatmospheric as the walls of the sphincter are pulled apart to create this expanding space. This drop to subatmospheric pressure within the pharyngoesophageal segment implies sphincter opening.^{1,8-11} As the fluid bolus enters the open sphincter, the pressure rises from the subatmospheric drop to a supraatmospheric pressure (T_2). As the bolus tail leaves the segment, there is again an abrupt rise in pressure (T_3), representing closure of the esophageal lumen against the pressure ports. The maximal pressure reached in this rapid ascent is the result of the passage of the pharyngeal stripping wave (T_4) through the cricopharyngeal muscle and into the cervical esophagus.

Assessment in the Study Population

Each tracing was evaluated for the presence of T_1 (see Fig. 3) during the opening pressure. The lowest pressure recorded was defined as the intrasphincteric pressure drop and was used to assess sphincter opening. Sphincter opening was said to be normal if the pressure became subatmospheric and was defined as impaired if this did not occur. True sphincter relaxation can be measured only with an electromyograph. However, for a normal subatmospheric intrasphincteric pressure drop to occur, there must be complete sphincter relaxation. In this study, a normal subatmospheric intrasphincteric pressure drop was equated with normal sphincter relaxation.

The resistance to pharyngoesophageal flow relates to the compliance of the cricopharyngeal and cervical esophageal muscles and the amplitude of the pharyngeal contraction waves. It was assessed by measuring the intrabolus pressure. Intrabolus pressure in the proximal pharyngoesophageal segment was measured at T_b (see Fig. 2). Intrabolus pressure in the UES and the more distal pharyngoesophageal segment was measured during the passage of the head (T_2) and tail (T_3) of the bolus through the open UES (see Fig. 3). The highest pressure measured at T_b (see Fig. 2), T_2 (see Fig. 3), or T_3 (see Fig. 3) was considered to be the intrabolus pressure for a swallow. The average of five swallows was used to calculate the final intrabolus pressure.

Table 2. SEVERITY AND FREQUENCY OF DYSPHAGIA

Grade	Dysphagia Severity	n (%)	Frequency		
			Daily (%)	Weekly (%)	Monthly (%)
0	None	20 (19)			
I	Occasionally with coarse foods	15 (14)	8 (53)	4 (27)	3 (20)
II	Require liquids to clear	28 (26)	21 (75)	7 (25)	
III	Require a semi-liquid diet	39 (36)	34 (87)	4 (10)	1 (3)
IV	Dysphagia with liquids and solids	5 (5)	4 (80)	1 (20)	

Table 3. SEVERITY AND FREQUENCY OF DYSPHAGIA IN THE 31 PATIENTS UNDERGOING MYOTOMY

Dysphagia Severity		n (%)	Frequency		
			Daily (%)	Weekly (%)	Monthly (%)
0	None	1 (3)			
I	Occasionally with coarse foods	3 (9)	2 (66)		1 (33)
II	Require liquids to clear	9 (30)	7 (78)	2 (22)	
III	Require a semi-liquid diet	14 (45)	12 (86)	2 (14)	
IV	Dysphagia with liquids and solids	4 (13)	4 (100)		

A patient was considered to have an elevated intrabolus pressure when the pressure measured with a 5-ml swallow was greater than the 95th percentile for 56 normal subjects (>16.3 mmHg). A patient was classified as having low pharyngeal contraction amplitudes when the pressure measured with a 5-ml swallow was less than the fifth percentile for 56 normal subjects (<27.7 mmHg).

Myotomy Technique

Cricopharyngeal myotomy was performed through a left cervical incision along the anterior border of the sternocleidomastoid muscle. The omohyoid muscle was divided at its pulley and the strap muscles were divided at their clavicular and sternal insertions. The carotid sheath was retracted laterally and the thyroid and trachea were retracted medially. Identification of the diseased pharyngoesophageal segment was made using visual cues and the position of an indwelling nasogastric tube marked to correspond with the upper border of the UES, identified during the presurgical manometric evaluation. The myotomy was started in the inferior constrictor and just above the level of the indwelling nasogastric tube, and was extended across the cricopharyngeus down the cervical esophagus for 5 cm or more. If possible, a muscle strip 0.5 to 1 cm wide was excised. The total length of the myotomy was 7 to 10 cm.

The myotomy was performed under local anesthesia in 2 patients and general anesthesia in the remaining 29 patients. A laparoscopic Nissen fundoplication was done concomitantly in three patients. An additional three patients had a previous antireflux repair consisting of a laparoscopic Nissen in two and a transthoracic Nissen in one.

Statistical Analysis

All data are expressed as median \pm interquartile range. Paired data were analyzed using the Wilcoxon signed rank test. Categorical data were analyzed using a chi square test. A stepwise logistic regression was performed to correlate predictors of outcome. Offered to the regression procedure were age (younger than 75, or 75 or older), gender, a discernible or nondiscernible cause for the dysphagia, the presence or absence of a cerebrovascular accident, normal

or abnormal intrabolus pressure, normal or impaired sphincter opening, and abnormal or normal pharyngeal contraction amplitudes. To ease clinical interpretation of statistical models, outcome was coded as a two-level variable: 1 = excellent or good, 2 = fair or poor. To stay in the model, covariates were required to be significant at the 0.05 level.

RESULTS

Clinical Features of Pharyngeal Swallowing Disorders

Dysphagia was the most common symptom, occurring in 90 (84%) of 107 patients. It was the primary presenting symptom in 65 (61%). The severity and frequency of dysphagia are shown in Tables 2 and 3. A history of choking and coughing when eating was present in 59 (55%) of the 107 patients and was the primary presenting symptom in 19 (18%). Regurgitation was present in 46 (43%) of the 107 patients but was the primary symptom in only 2 patients. Twenty-one (20%) patients complained of nasal regurgitation of food. Thirty-five (33%) noted an alteration in the quality, strength, or pitch of their voice. Pneumonia was a complication in 23 (21%) of the 107 patients. Two patients died while awaiting surgery; both deaths were related to respiratory complications from aspiration. Overall, the median duration of symptoms was 36 months (range 2 to 696).

A history of weight loss was given by 40% of the 107

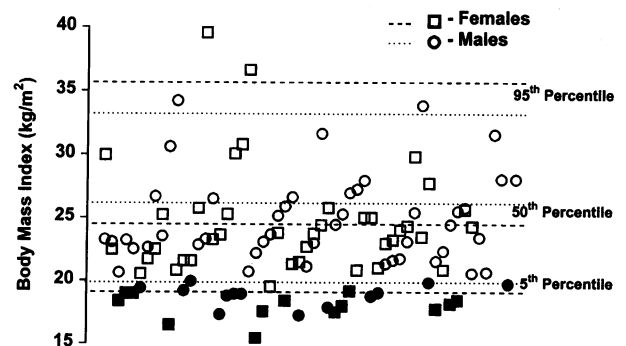


Figure 4. Body mass index (kg/m^2) of all the patients relative to the 5th, 50th, and 95th percentiles of the general population.¹² Solid symbols depict the 26 (24%) patients below the fifth percentile.

Table 4. RADIOLOGICAL FINDINGS

	Unoperated Patients n = 76 (%)	Myotomy Patients n = 31 (%)
Pharyngeal dilation	8 (11)	6 (20)
Pharyngeal pooling/stasis	17 (22)	13 (42)
Penetration/aspiration	21 (28)	17 (55)
Cricopharyngeal bar	15 (20)	17 (55)
Normal study	45 (60)	2 (7)

patients. The median body mass index was 22.7 ± 5.84 for the women and 23.08 ± 4.88 for the men. The index was below the fifth percentile of the population¹² in 26 (24%) of the 107 patients (Fig. 4) and in 13 (42%) of the 31 patients undergoing myotomy. Twenty-one (19%) of the 107 patients could not maintain their nutrition and required supplemental or total gastrostomy feedings.

The radiologic findings are shown in Table 4. Patients who had a myotomy tended to have more severe radiographic abnormalities.

The patients were divided into two broad categories based on the manometric assessment of UES opening (Fig. 5). Forty-four patients had manometric evidence of a subatmospheric intrasphincteric pressure drop and thus normal sphincter opening and indirectly normal sphincter relaxation. Based on their intrabolus pressure, these patients could then be further subdivided into 25 patients with no evidence of outflow obstruction to bolus transport across the pharyngoesophageal segment (normal intrabolus pressure)

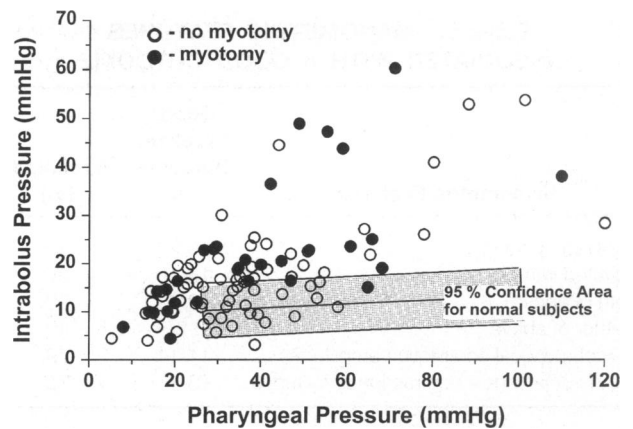


Figure 6. Mean peak pharyngeal contraction pressure and intrabolus pressure for 5-ml swallows in all the patients. Solid symbols depict the patients who underwent myotomy. The shaded area represents the 95% confidence level for normal subjects.

and 19 with outflow obstruction to bolus transport (elevated intrabolus pressure).

Sixty-three patients failed to show a subatmospheric intrasphincteric pressure drop and thus had evidence of impaired sphincter opening and relaxation. This group could be further subdivided into 24 patients with no evidence of outflow obstruction (normal intrabolus pressure) and 39 with outflow obstruction (elevated intrabolus pressure).

A bolus pressure is generated not only by the resistance to flow through the pharyngoesophageal segment but also because of the amplitude of the peak pharyngeal contraction pressures. The relation between these two pressures is critical (Fig. 6). A patient with a high resistance could have a normal bolus pressure if the peak pharyngeal contraction pressure was weak. Because of this relation, a patient with significant resistance to flow through the pharyngoesophageal segment could have a normal bolus pressure. In such patients, the only manometric abnormality reflecting abnormal function would be the lack of a subatmospheric intrasphincteric pressure drop, indicating impaired sphincter opening.

Outcome of Surgical Myotomy

There were no deaths within 30 days after surgery. The postsurgical morbidity rate was 16%; complications consisted of pneumonia in two patients, pulmonary edema in one, and a neck hematoma requiring reexploration in two. One of these patients also had a temporary tracheostomy tube inserted. The median hospital stay was 4 days (range 2 to 29).

All 14 patients with no discernible coexisting illness had an excellent or good outcome. This occurred in 63% (5/8) of the patients who had a prior cerebrovascular accident and in 59% (10/17) of those who had a coexisting neuromuscular disease. Overall, 23% (7/31) of patients had a poor outcome; this was the result of persis-

Manometric evaluation of the Pharyngoesophageal Segment

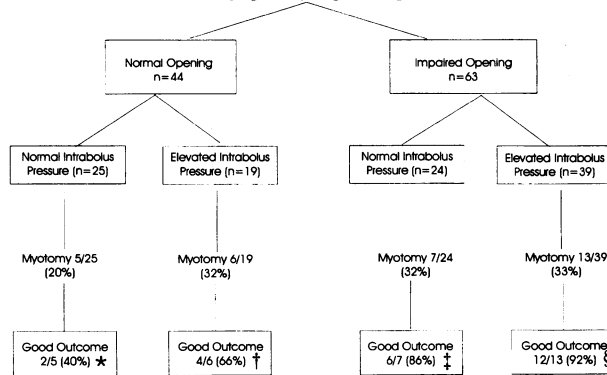


Figure 5. Flow diagram of results based on the manometric evaluation of UES opening and outflow resistance. Patients with a normal manometric subatmospheric pressure drop were assigned to the normal opening group, those who failed to achieve a subatmospheric pressure drop to the impaired opening group. Patients with normal sphincter opening were subdivided into those with a normal or an elevated intrabolus pressure. Similarly, patients with impaired sphincter opening were subdivided into those with a normal or an elevated intrabolus pressure. The number of patients undergoing myotomy and the results are depicted for each group. Significance * and † vs. ‡ and § p = 0.024; * vs. § p = 0.017; * vs. ‡ p = 0.098; † vs. ‡ p = 0.0376.

Table 5. MANOMETRIC FEATURES ASSOCIATED WITH A GOOD OUTCOME

Manometric Features	Good/ Excellent Outcome (n)	Percentage (%)
Impaired opening	18/20	90
Elevated intrabolus pressure	16/19	84
Both of above	12/13	92
Neither of above	2/5	40
Low pharyngeal contraction amplitudes	11/14	79
Normal pharyngeal contraction amplitudes	13/17	76

tent dysphagia in all seven, three of whom had continued aspiration. One of the seven patients had a myositis of the pharyngeal muscles with a vocal cord palsy secondary to diphtheria, and another had severe xerostomia from radiation injury. Eight patients required the use of a gastrostomy tube perioperatively for full or supplemental feedings. Sixty-three percent (5/8) had an excellent or good outcome after myotomy, and the tube was subsequently removed in seven.

An excellent or good outcome was achieved in 5 (84%) of the 6 patients who had presurgical pharyngeal dilatation on the video esophagram and in 9 (69%) of the 13 patients who had pooling of contrast. Similarly, an excellent or good outcome was achieved in 14 (82%) of the 17 patients who had a cricopharyngeal bar and in 12 (71%) of the 17 patients who had visual evidence of laryngeal penetration and aspiration during the presurgical video esophagram.

The manometric features associated with a good or excellent outcome are shown in Table 5.

At the multivariate level, only two factors significantly predicted a successful outcome: no discernible cause for the dysphagia (odds ratio = 7.5; 95% confidence level 1.1 to 49.3) and impaired sphincter opening (odds ratio = 8.4; 95% confidence level 0.9 to 81). An excellent or good outcome was achieved in all nine patients who had both a nondiscernible cause for their dysphagia and impaired sphincter opening (odds ratio = 20; 95% confidence level 0.9 to 429.9).

Effect of Myotomy on Manometry

Twelve patients had postsurgical manometry studies; only 1 of the 12 had normal opening before surgery. Of the 11 patients with impaired opening, 10 achieved a postsurgical subatmospheric pressure drop consequent with a normal opening pressure profile (Figs. 7 and 8). The median intrabolus pressure of 19 ± 29 mmHg was significantly reduced to 10.8 ± 10.1 mmHg after surgery ($p = 0.002$, Figs. 9 and 10). A good clinical outcome was achieved in 92% (11/12) of the patients who showed recovery of a

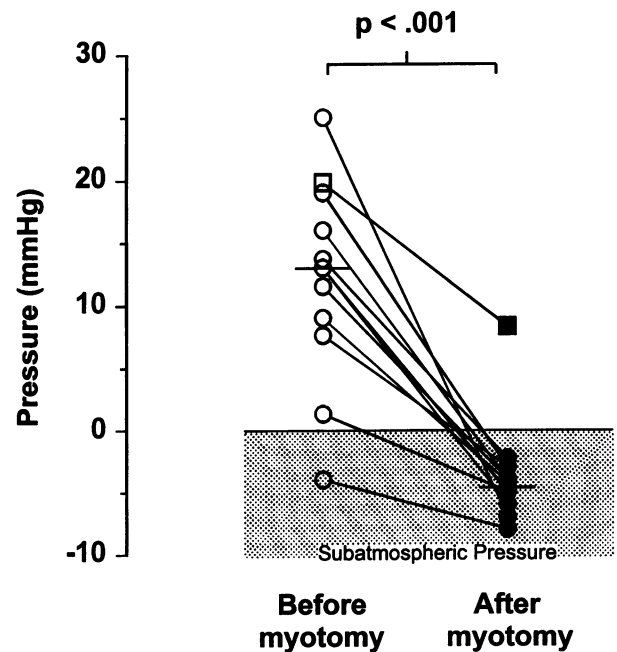


Figure 7. Intrasphincteric pressure at opening before and after myotomy ($n = 12$). The median intrasphincteric pressure drop was significantly lower after surgery than before surgery ($p < 0.001$, Wilcoxon signed rank test). The circle symbol represents patients with a good outcome. The square symbol represents the single patient with a poor outcome.

normal opening pressure profile and a reduced intrabolus pressure after surgery. The median pharyngeal contraction amplitude of 33 ± 40 mmHg was significantly reduced to 27 ± 29 mmHg after surgery ($p = 0.023$, Fig. 11). In particular, the relation between pharyngeal contraction pressures and intrabolus pressure moved toward normal or became normal (Fig. 12).

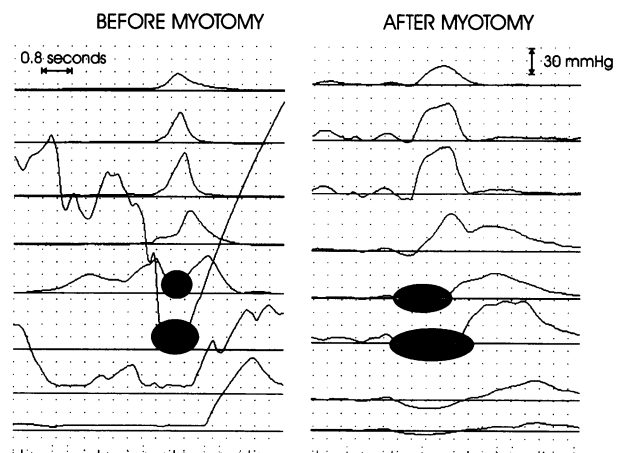


Figure 8. Manometric tracing of a dry swallow in a patient before and after myotomy. The baseline for each channel is atmospheric pressure. The shaded area represents the opening intersphincteric pressure in channels 5 and 6. Before myotomy, the pressure is supraatmospheric, reflecting impaired opening of the UES. After surgery, the intersphincteric pressure is subatmospheric, indicating restored UES opening.

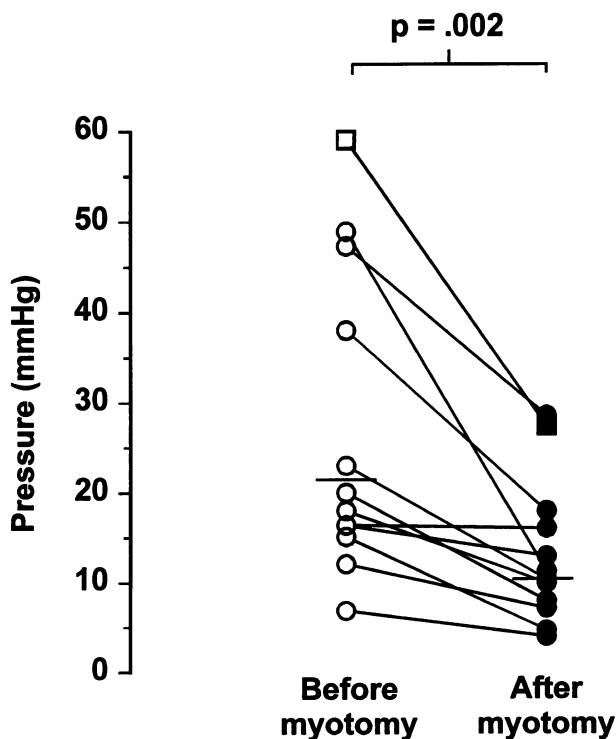


Figure 9. Intrabolus pressure before and after myotomy (n = 12). The median intrabolus pressure was significantly lower after surgery than before surgery (p = 0.002, Wilcoxon signed rank test). The circle symbol represents patients with a good outcome. The square symbol represents the single patient with a poor outcome.

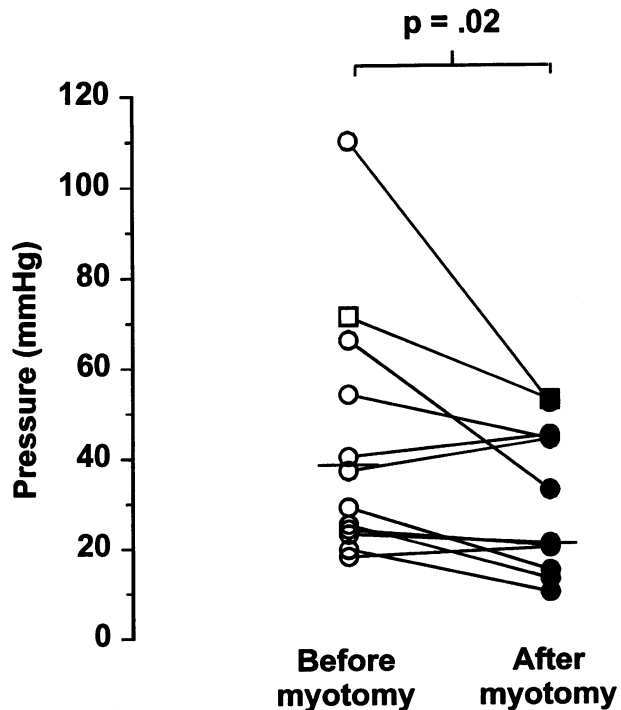


Figure 11. Peak pharyngeal contraction pressure before and after myotomy (n = 12). The median peak pharyngeal contraction pressure was significantly lower after surgery than before surgery (p = 0.02, Wilcoxon signed rank test). The circle symbol represents patients with a good outcome. The square symbol represents the single patient with a poor outcome.

DISCUSSION

This study shows that the results of myotomy were excellent or good in all patients with no discernible underlying disease but were not as good in patients with neuropathic or myopathic disease. Our results with myotomy were similar to those of other studies, which have reported that approx-

imately two thirds of patients will benefit.¹³⁻²⁶ In the past, a pharyngeal swallowing disorder implied failed relaxation of the cricopharyngeal muscle and was thought to be responsible for the dysphagia in stroke patients. Kahrilas et al.²⁷ first suggested impairment in sphincter opening as an

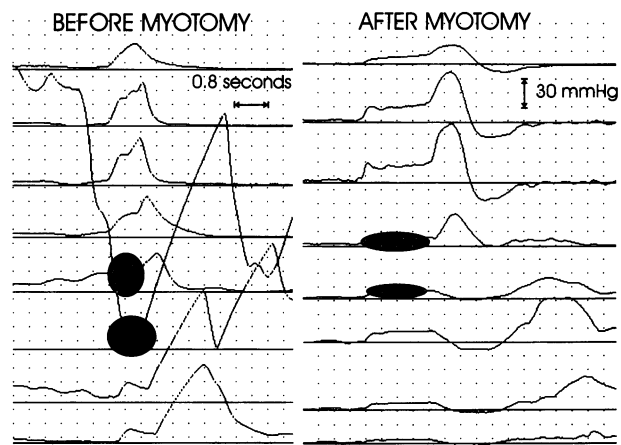


Figure 10. Manometric tracing of a 5-ml swallow in a patient before and after myotomy. The baseline for each channel is atmospheric pressure. The shaded area depicts the intrabolus pressure during the swallow. The maximal intrabolus pressure before surgery in this tracing was approximately 30 mmHg; after surgery, it was 8 mmHg.

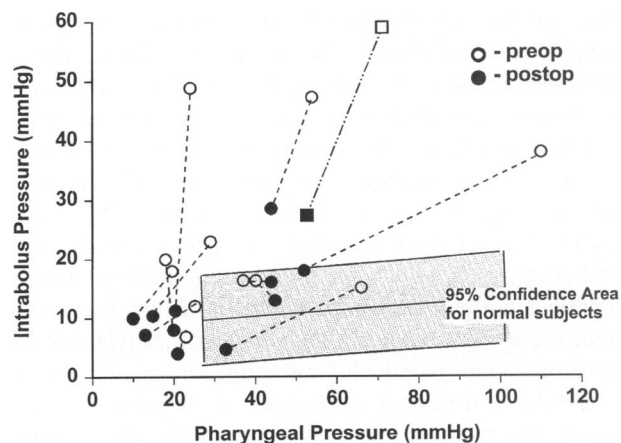


Figure 12. The relation between the mean peak pharyngeal contraction pressure and intrabolus pressure for 5-ml swallows in the 12 patients studied before and after myotomy. The shaded area represents the 95% confidence level for normal subjects. The circle symbols represent patients with a good outcome. The square symbol represents the single patient with a poor outcome.

alternative explanation. This was the result of weakness of the suprahyoid and infrahyoid strap muscles and the failure to elevate the larynx. They also showed that volitional augmentation of opening can occur during the swallow in normal subjects and in patients after a stroke.^{27,28} A recent publication reported that sternohyoid muscles in stroke patients showed characteristic degenerative and myopathic changes on biopsy.²⁹ It is feasible that weakness in the elevators or imbalance in the depressors and elevators of the larynx can cause impaired sphincter opening and is the cause of the dysphagia in these patients after a cerebrovascular accident. Identification of defective sphincter-opening mechanics would therefore be important in selecting patients who would benefit from surgery. Appropriate management would then entail identification of patients with impaired sphincter opening and the performance of a myotomy, which we have shown can restore sphincter-opening mechanics.

In contrast to patients with stroke, the major pathophysiology in patients with underlying myopathic disease is decreased distensibility of the cricopharyngeus and cervical esophagus as a result of histologic changes in the muscle (degeneration, fibrosis, and narrowing).³⁰⁻³² The fibrosis of the cricopharyngeus and cervical esophageal muscles impairs the opening of the pharyngoesophageal segment by decreasing its compliance. As a consequence, resistance to flow develops, resulting in a high intrabolus pressure. In this situation, a surgical myotomy restores compliance by widening the narrowed pharyngoesophageal segment. Impaired opening can also occur in these patients as a result of weakness of the suprahyoid and infrahyoid musculature, similar to that seen in patients with strokes. In this scenario, the sphincter relaxes normally during the swallow but fails to open because it is not elevated and pulled apart by the anterior-superior traction forces of the strap muscles mediated via the hyoid.

The UES is normally open and relaxed on arrival of a bolus, and this can be depicted manometrically by a subatmospheric drop in pressure before any radiologic contrast can be seen in the UES. Any impairment in UES relaxation and opening is evident as a failure of the intersphincteric pressure to fall during the opening phase of the swallow. In this situation, the intrabolus pressure is elevated as the fluid bolus meets the increased outflow resistance at the level of the UES. This situation occurred in 39 patients in this study (see Fig. 5). If, however, the glossopharyngeal contraction amplitudes are less than normal, the intrabolus pressure is within the normal range. In this situation, a myotomy can still be of benefit by reducing the active and passive tone of the muscles and thereby decreasing the resistance to flow through the pharyngoesophageal segment. As a consequence, it is easier for the weak glossopharyngeal contractions to overcome outflow resistance. For this reason, a poor pharyngeal peak contraction pressure is not a predictor of poor outcome. Selecting the patients who will benefit from a myotomy in this situation is difficult because of the

absence of an elevated bolus pressure. Some help can be obtained by plotting the peak pharyngeal contraction pressure and the bolus pressure that occurs with progressive increases in the volume of the swallowed bolus.

Why a myotomy should improve sphincter opening was something of a mystery to us until we realized that division of the sternohyoid and omohyoid muscles might improve the F_{traction} of the sphincter opening equation. Division of the hyoid depressor muscles (omohyoid and sternohyoid) may contribute to the improved elevation of the larynx.

Crucial to the evaluation of pharyngeal swallowing disorders is use of the eight-channel manometry catheter. It is important to have the eight pressure ports closely spaced; this facilitates proper placement in the UES. Before the swallow, one sidehole should be in the distal UES and one just above the proximal UES border. This facilitates the recording of the anticipated subatmospheric intersphincteric pressure drop. Dent sleeve manometry catheters are inappropriate for this study because they cannot measure the subatmospheric pressure drop. Solid-state catheters are limited by the number of and spacing between transducers.

The most important manometric marker in selecting patients for myotomy is the absence of the subatmospheric intrasphincteric pressure drop. When combined with an increased intrabolus pressure, the surgeon has the mechanical indicators that myotomy will result in improved swallowing. In a recent paper, Kelly³³ echoed the sentiment of others in questioning the usefulness of manometry in the assessment of pharyngeal swallowing disorders. In contrast, this study shows that by identifying manometric correlates of defective sphincter opening and increased outflow resistance, selection of patients can be dramatically improved. The effect of a myotomy is purely mechanical; therefore, it is only logical that any selection strategy should focus on the mechanical aspects of disordered swallowing.

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Discussion

DR. F. GRIFFITH PEARSON (Toronto, Ontario): I enjoyed the presentation of this paper and appreciate the opportunity to review the detailed manuscript in advance of the presentation. There is considerably more information in the complete manuscript. Over the years, many patients with neurological disorders such as post-stroke dysphagia have been operated with little evaluation beyond the assumption that the "simple little" operation of cricopharyngeal myotomy may be helpful. Disappointed patients are at least as common as satisfied customers using this superficial approach. The detailed and sophisticated manometry of swallowing which is described in this paper is little known by most surgeons, and indeed by many gastroenterologists. This type of careful and detail study of the upper esophageal sphincter is not achieved in most esophageal function laboratories because of the rapid sequence of changes which occurs during the brief moment of a swallow. These events occur so quickly that they may not be picked up by standard records. Even more importantly, movement of the larynx and upper esophageal sphincter occurs over several centimeters during the duration of a swallow, which displaces the anatomic relationship between the manometric sensor and the structures such as the upper esophageal sphincter. The authors describe their methodology in detail, and appear to record events which can be measured and interpreted with much more accuracy than in most laboratories. The abnormal mechanics and pressure that they identify in these patients appear to offer a plausible explanation for the presence of dysphagia which is relieved by dividing the cricopharyngeal sphincter in selected cases. Furthermore, similar observations have been reported by Ian Cook and colleagues in New South Wales, Australia. Many of the comments I was going to make have already been made. But I still have trouble understanding exactly where this complicated manometric evaluation fits into the preoperative assessment of these patients. As Dr. Nauenheim pointed out, only 13 of your patients had a high opening pressure and high intra-bolus pressures. As I read your manuscript, five patients had completely normal manometric studies. In addition, I think, as I recall the details in the manuscript, there were 15 patients who were offered myotomy and did not undergo the procedure. Is that due to patient refusal or were these patients instructed on the basis of manometric findings, that they might have a satisfactory result?

DR. RODNEY J. MASON (Los Angeles, California): Only five of our patients had a normal manometry study. The outcome was poor in these patients with only two that did well. So it does seem that you can expect to have good results if you can select those patients who have an abnormal manometry study, whereas if you have a normal manometry study you can expect a less favorable outcome.

With regard to the last question we did offer those patients a myotomy. In some of those patients, the insurance company refused to pay for the procedure at our hospital and in others, the patients themselves didn't want to have the operation. So it was a sort of an equal mix with a combination of both patient refusal and insurance refusal.