# The Pharyngo-Esophageal Segment (PES)

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#### **Functional anatomy of the PES**

The upper esophageal sphincter (UES) is a 2.5 to 4.5 cm manometric high-pressure zone located between the pharynx and esophagus (Figure 1).

Because of its location, this region has also been referred to as the pharyngo-esophageal segment or PES. The UES specifically refers to the intra-luminal high-pressure zone visualized on manometry. The PES refers to the anatomic components that make up the high-pressure zone. The UES and PES are synonymous terms and may be used interchangeably. The cricopharyngeous muscle (CPM) makes up only one component of the PES. The CPM is not synonymous with the UES and PES. The PES is modifiable with therapy and surgery. It is for this reason that the PES has captured the interest of a countless number of dysphagia clinicians and surgeons.

The PES is made up of the inferior pharyngeal constrictor (IPC), the CPM, and the most proximal cervical esophagus (Figure 2).

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Figure 1. Manometric profile of upper esophageal sphincter. Small black arrow demarcates distal UES at 22.5 cm from nasal vestibule. Large black arrow demarcates proximal UES at 20.5cm from nasal vestibule. Mean UES resting pressure = 80mm Hg.



Figure 2. Pharyngo-esophageal Segment (PES).

All three muscles help maintain resting tone. The function of the PES is to prevent aerophagia during respiration and phonation and to protect against the aspiration of refluxed gastric and esophageal contents. The PES is tonically contracted at rest. It reflexively opens during deglutition, eructation (burping), and vomiting. Distension of the esophagus, emotional stress, pharyngeal stimulation, and possibly acid instilled into the esophagus all reflexively tighten the PES (1-4). Of the three components that make up the PES, only the CPM contracts and relaxes during all reflex tasks. It is for this reason that many clinicians regard the CPM as the only true sphincter.

#### Innervation of the cricopharyngeus muscle (CPM)

The CPM is a c-shaped muscle attached to the lateral laminae of the cricoid cartilage. It consists of a horizontal pars fundiformis and an oblique pars obliqua. A combination of slow type I and fast type II muscle fibers allow the CPM to maintain a constant basal tone and to rapidly expand and contract when necessary. Intricate micro-dissections in 27 persons undergoing total laryngectomy by Sasaki et al. suggest that the CPM receives dual ipsilateral innervation from the pharyngeal plexus (PP) and the recurrent laryngeal nerve (5). The PP projects to the posterior and the RLN projects to the anterior motor units of the muscle. Sensory information from the CPM is provided by the glossopharyngeal nerve and cervical sympathetics.

#### **PES Opening**

The act of swallowing depends upon adequate and timely PES opening. Opening of the PES depends upon muscular relaxation, elevation of the larynx, and pharyngeal contraction. Cook et al. described 5 phases of PES opening (6). In the 1st phase there is an inhibition of tonic PES contraction (Figure 3).



Figure 3. Phase I of PES opening: Inhibition of tonic PES contraction. Decreased activity is seen in the EMG signal (arrow - inset). The bolus is prepared in the oral cavity and the larynx has not yet begun to elevate.



Figure 4. Phase II of PES opening: Hyolaryngeal excursion produces passive opening of the PES.

This is followed by elevation of the hyoid and larynx. Hyolaryngeal excursion provides passive opening of the PES (Phase II – Figure 4).

The traction force provided by elevation appears to be more important to PES opening than muscular inhibition since the PES can open by active distraction alone, but muscular relaxation without elevation will not open the PES. This has significant clinical implications as swallowing in individuals with good hyolaryngeal elevation but poor PES relaxation is possible and often encountered. Swallowing in individuals who can relax their CP but cannot elevate their larynx has not been observed.



Muscular relaxation without elevation will not open the PES.

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Phase III of PES opening involves distension of the PES through bolus size and weight (Figure 5).

This phase relies upon pharyngeal and lingual peristalsis to propel the bolus past the spacious

hypopharynx, through the narrowed but expanding PES, and into the cervical esophagus. The elasticity of the PES allows it to be opened by the increasing pressure exerted by the passing bolus. After the bolus passes, this elasticity causes a passive collapse of the PES (Figure 6 - Phase IV).



Figure 5. Phase III of PES opening: Distension of the PES through bolus size and weight. Note non-obstructing CP bar (arrow).



Figure 6. Phase IV of PES opening. Passive collapse of the PES after the bolus passes through.

## The Pharyngo-Esophageal Segment (PES)

Phase V involves PES closure through active contraction (Figure 7).





Figure 7. Phase V of PES opening: Closure of PES through active contraction. Note the burst of electrical activity on EMG (small arrow) that corresponds to a transient elevation in intra-luminal pressure on manometry (large arrow) before a return to baseline electrical activity and pressure (inset).

#### **Disease processes that may cause PES dysfunction**

A disease process that affects any one of the 5 phases of PES opening can cause dysphagia (Table 1).

Oropharyngeal carcinoma	Dermatomyositis	Diabetes
Esophageal carcinoma	Inclusion body myositis	Diphtheria
Benign esophageal tumor	Hyperthyroidism	Rabies
Zenker's diverticulum	Idiopathic	Lead poisoning
Laryngopharyngeal Reflux	Radiation therapy	Polymyositis
Pharyngitis	Brainstem tumor	Scleroderma
Post-surgical change	ALS	Muscular dystrophies
Foreign body	Huntington's chorea	Myxedema
CVA	Poliomyelitis	Botulism
Parkinson's	Spinocerebellar degeneration	Trauma (iatrogenic)
Inflammatory myopathies	Syringobulbia	

Table 1. Causes of PES dysfunction.

Discussion of each pathologic entity is beyond the scope of this manuscript. The remainder of this report will focus on the diagnosis and treatment of PES dysfunction.

The diagnosis of PES dysfunction is one of the most difficult challenges facing the dysphagia clinician. While seemingly straightforward, differentiating pharyngeal weakness from PES dysfunction can be challenging. The distinction between inadequate pharyngeal strength, poor laryngeal elevation, and inadequate PES relaxation is essential. Patients with poor pharyngeal strength or inadequate elevation respond better to therapy and typically make very poor surgical candidates. Persons with inadequate relaxation but good strength and elevation, however, often respond well to surgery. The diagnosis of PES dysfunction is made by a combination of bedside swallow evaluation, endoscopy, manometry, and fluoroscopy.

#### **Bedside Swallow Examination**

The bedside swallow examination begins with a thorough history and physical. A rheology assessment identifies an individual's most difficult swallowing consistency.

- Difficulty with thin liquids alone suggests a sensory deficit and weighs against a primary PES abnormality.
- Isolated solid or combined solid and liquid food dysphagia indicates a problem with pharyngeal strength, PES function or esophageal emptying.
- An individual who localizes his dysphagia to the cervical region does **NOT** necessarily have a pharyngeal swallowing abnormality. One-third of patients who localize their dysphagia at or above the suprasternal notch will have an esophageal abnormality such as esophageal stricture or neoplasm (7).
- Patients who localize their swallowing problem to the chest usually **DO** have an esophageal abnormality responsible for the dysphagia.
- Thus, liquid food dysphagia and dysphagia localized to the chest suggest that the swallowing abnormality is not localized to the PES.

The thyroid notch and hyoid bone are palpated as the patient is instructed to perform a dry swallow.

- A larynx that does not elevate suggests that the PES is unlikely to open.
- A larynx that elevates appropriately, however, may also have a PES abnormality such as cricopharyngeal achalasia or PES fibrosis.

If appropriate, the patient is administered various different food consistencies and the act of swallowing is observed.

• The performance of multiple swallows and a wet vocal quality suggest the presence of residual food material in the endolarynx or hypopharynx. This may be an indication of PES dysfunction or pharyngeal weakness.

Although the bedside swallow evaluation is beneficial, it is often **inadequate** to distinguish between pharyngeal weakness and primary PES dysfunction. In addition, the bedside examination **may miss aspiration in up to 40%** of individuals (8). Other diagnostic modalities are necessary to localize the site of swallowing difficulty to the PES.

#### **Endoscopic Swallow Evaluation**

The fiberoptic endoscopic evaluation of swallowing (FEES) is an essential part of the comprehensive dysphagia workup. Endoscopy allows the clinician to evaluate secretions, edema, laryngeal sensation, the presence of any mucosal abnormalities, and vocal fold mobility. Pharyngeal strength can be assessed with the pharyngeal squeeze (PS) maneuver. The maneuver was introduced by Bastian in 1993 (9). It is performed by having the patient produce a forceful "eee" sound during flexible fiberoptic laryngoscopy. The clinician visualizes the contraction of the lateral pharyngeal walls and assesses the integrity of pharyngeal muscle function (Figure 8).



Figure 8. Pharyngeal Squeeze Maneuver. a) Pharynx at rest. b) Pharynx during a normal pharyngeal squeeze maneuver. Note apposition of posterior pharyngeal walls to aryepiglottic folds and obliteration of pyriform sinuses (yellow arrow heads).

Perlman et al. and Setzen et al. both demonstrated that pharyngeal strength as assessed with the PS maneuver predicts the presence of aspiration of pureed and liquid food in patients with dysphagia (10). Although endoscopy can readily evaluate pharyngeal strength, its ability to diagnose PES dysfunction is more difficult. An intact PS with post-swallow residuals in the hypopharynx **suggests** outlet obstruction at the level of the PES. An absent PS suggests that pharyngeal strength, not PES function, is primarily responsible for the swallowing abnormality.

#### **Pharyngeal and UES Manomety**

Manometry is an essential diagnostic modality in the evaluation of PES function. Manometry can assess pharyngeal and hypopharyngeal strength, PES relaxation, and pharyngo-PES coordination. We perform manometry using a Koenigsberg 3-channel probe (Sandhill EFT catheter; Sandhill Scientific Inc., Highlands Ranch, CO, USA). The 4.5 mm-diameter catheter has two circumferential and one directional solid-state pressure sensors at 5, 8, and 10 cm from the tip. The catheter is inserted transnasally into the esophagus just below the PES. Baseline intra-esophageal and pharyngeal pressures are established. The PES pressure is determined by a 0.5cm station pull-through technique (Figure 1).



The distal circumferential sensor is placed just proximal to the high-pressure zone of the PES. This positions the hypopharyngeal sensor approximately 3cm and the pharyngeal sensor 5cm above the PES. Pharyngeal-PES activity is recorded during successive swallows of 10cc saline aliquots. Normal resting pressure of the PES (Figure 9) is 73 (+/-29) mm Hg (12).

Figure 9. Normal Pharyngeal/PES Manometry. a) Baseline PES pressure, b) Onset of pharyngeal contraction, c) Onset of hypopharyngeal contraction, d) Nadir of PES relaxation



Figure 10. High resting PES pressure with complete relaxation in a person with globus. a) High baseline PES pressure (173 mm Hg).

A high PES pressure (Figure 10) suggests "spasm" of the cricopharyngeous. CPM spasm has been associated with the presence of globus and reflux (13-15).

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Pharyngeal strength can be assessed with the pharyngeal squeeze maneuver.

### **Diagnosing PES Dysfunction**



Incomplete PES relaxation has been referred to as cricopharyngeal dysfunction or CP achalasia (Figure 11).

Figure 11. Failure of PES relaxation (black arrow).

Normal baseline PES pressure should fall to 0 mm Hg or less (see nadir PES pressure Figure 9). The onset of pharyngeal contraction is usually an abrupt elevation in pressure (Figure 9-c). If the PES fails to relax normally, a prominent hypopharyngeal intrabolus pressure may be recorded (Figure 12).



Figure 12. Hypopharyngeal intrabolus ramp pressure. The black arrow indicates the onset of a normal pharyngeal contraction. The red arrow indicates the presence of hypopharyngeal intrabolus (ramp) pressure. Note also the failure of PES relaxation in the second swallow (blue arrow).

In addition to PES relaxation, pharyngeal-PES coordination is also evaluated. The PES pressure should drop with the initiation of the swallow. It should remain relaxed until the bolus exits the sphincter and the hypopharyngeal pressure wave moves into the esophagus. If the pharynx contracts before or after the PES relaxes, obstruction at the level of the PES may occur. Incomplete and poorly coordinated PES relaxation and the presence of hypopharyngeal intrabolus pressure suggest outlet obstruction at the level of the PES and may be indications for surgery on the CP muscle.

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#### Videofluoroscopy

The best visualization of pharyngeal/PES dynamics is with cinefluoroscopy. Stop-motion video allows a comprehensive evaluation of pharyngeal strength, laryngohyoid elevation, PES opening, and pharyngo-PES coordination. Objective data typically evaluated on fluoro include PES opening size (cm), hyoid and larynx to hyoid displacement (cm), the pharyngeal constriction ratio, PES opening duration, and oro- and hypopharyngeal bolus time (16, 17).

Normal PES opening increases with enlarging bolus size (Figure 13).

With larger bolus sizes, PES opening is 0.80cm (+/- 0.28). The measurement of PES opening is an important component to the fluoroscopic swallow evaluation. We frequently encounter many individuals with a CP bar who have normal PES opening. In fact, over 30% of elderly non-dysphagic persons have evidence of a CP bar on fluoroscopy (18). The presence of a bar does not imply the existence of dysphagia. *An individual with a CP bar and normal PES opening should be evaluated for an* 



Figure 13. PES opening (cm) by bolus size.

*alternative cause for her/his swallowing complaints.* One-third of people who localize their dysphagia to the cervical region will have an esophageal etiology for their dysphagia (Figures 14, 15).



Figure 14. Cricopharyngeal bar in a 62 year-old woman with normal PES opening (0.75cm). Endoscopy revealed high-grade erosive esophagitis. Her dysphagia resolved with reflux therapy.



Figure 15. Cricopharyngeal bar with a pathologically narrowed PES (White arrow -0.19cm). This patient responded well to balloon dilation of the PES.

Normal elevation of the larynx and hyoid varies by gender. The accurate calculation of laryngohyoid elevation is essential. Women elevate their larynx 1.09 (+/- 0.57) cm and men elevate their larynx 1.29 (+/- 0.47) cm. An individual whose larynx does not elevate adequately will not be able to open the PES, even after CP myotomy. Performing CP surgery on an individual with poor laryngeal elevation is hazardous and likely to fail.

The pharyngeal constriction ratio (PCR) is an accurate surrogate measure of pharyngeal strength. The PCR is the maximal pharyngeal area during passage of a bolus divided by the pharyngeal area with the bolus held in the mouth. Incomplete pharyngeal obliteration along with a lack of a descending pharyngeal contractile wave may be seen in the lateral projection of a videofluoroscopic study of swallowing and indicates pharyngeal muscular weakness. As pharyngeal constriction diminishes, the PCR increases. The PCR has been useful in assessing pharyngeal function in patients of differing age and gender with dysphagia secondary to a diverse



assortment of disorders. The PCR has also been utilized to monitor changes in pharyngeal function over time and after treatment. The ability of fluoroscopy to objectively evaluate the interrelationship between PES opening, laryngohyoid elevation, and pharyngeal contraction makes fluoroscopy one of the most important elements of the dysphagia workup. We utilize a step-up approach to the management of PES dysfunction. We begin treatment with noninvasive dietary restriction and swallowing exercise and advance to medical and surgical treatment as necessary. The entire therapeutic armamentarium for treating PES dysfunction includes dietary restriction, traditional dysphagia therapy, transcutaneous electrical stimulation swallowing therapy, anti-reflux medication, dilation, chemical CP myotomy with botulinum toxin, surgical CP myotomy, and laryngohyoid suspension.

#### **Traditional Dysphagia Therapy**

Patients with PES dysfunction will typically swallow better with thin, slippery consistencies than with thick, viscous or solid food. Placing an individual on "slippery solids" may improve oral intake. When placing an individual on a slippery diet, however, great care should be given to evaluating laryngopharyngeal sensation. A laryngeal sensory deficit will increase the likelihood of thin liquid aspiration.

#### Mendelsohn Maneuver

The Mendelsohn maneuver is performed by having the patient hold the larynx in an elevated position for several seconds during the swallow. This simple maneuver has been shown to prolong laryngeal excursion and increase PES opening time by maintaining traction on the anterior PES wall (19). "

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In patients with a flaccid hemipharynx, head rotation toward the paretic side excludes these structures from the bolus pathway and allows pharyngeal pressure to be directed at the PES. This reduces the resistance of the PES that must be overcome by the pharyngeal contraction.

#### Shaker Exercise

The Shaker exercise is performed by having the patient lie flat on a bed or floor and perform three sustained head raises for 1 minute, interrupted by a 1-minute rest period. After the three head raises the individual performs 30 consecutive repetitions of head raisings. The entire routine is performed three times daily. Comparison of the Shaker to a "sham" exercise regimen revealed that the Shaker program significantly improved UES opening and laryngeal elevation (20).

#### **Transcutaneous electrical stimulation**

Electrical stimulation (electrotherapy) has been used in rehabilitative medicine to retard disuse atrophy, exercise striated muscle, and accelerate wound healing. The idea of utilizing electrical stimulation (ES) to rehabilitate the swallowing mechanism is relatively new. Park et al. administered electrical stimulation via an oral prosthesis placed on the soft palate (21). Aiming to re-educate neural pathways associated with the swallowing reflex with electrical stimulation, they achieved a 50% success rate in improving the swallow of patients already capable of oral feeding. Freed et al. reported the efficacy of transcutaneous ES in 63 persons with dysphagia (22). In this study, they compared dysphagia in patients treated with electrical stimulation to those treated with thermal stimulation. Leelamanit et al. reported their experience with synchronized ES in 23 persons with dysphagia and concluded that dysphagia was improved in these patients (23). A control group was not utilized. Electrical stimulation is now cleared to market for dysphagia therapy by

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Electrical stimulation is cleared to market for dysphagia therapy by the FDA

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the Food and Drug Administration (VitalStim Therapy, Chattanooga Group, Chattanooga, TN). We have recently completed a non-concurrent cohort study evaluating the efficacy of electrotherapy to traditional dysphagia therapy in a long-term acute care hospital (24). The data suggest that dysphagia therapy with transcutaneous electrical stimulation is superior to traditional dysphagia therapy alone. Individuals receiving ES therapy required fewer treatment sessions and displayed a trend toward a shorter length of hospitalization than persons receiving traditional dysphagia therapy. Although we are presently uncertain of the exact mechanism, we suspect that electrotherapy improves laryngohyoid elevation and pharyngo-UES coordination.

#### **Anti-reflux medication**

Many clinicians have hypothesized a relationship between gastroesophageal reflux disease (GERD) and PES dysfunction. The CP muscle is the last line of defense to the regurgitation of esophageal and gastric contents into the airway. Instillation of acid into the esophagus raises PES pressure (25, 26). Hypertrophy of the CP muscle is thought to be a protective consequence of GERD. Brady et al. documented premature contraction of the CP muscle in patients with GERD. They determined the positive predictive value of this finding to be 88% for the diagnosis of reflux. If reflux is associated with PES dysfunction, one may surmise that anti-reflux therapy can improve PES function. Patients with mild dysphagia caused by reflux-related PES dysfunction may be treated empirically. The currently accepted medical treatment for extra-esophageal manifestations of reflux disease is twice-daily therapy with proton pump inhibitors (27). Currently available proton pump inhibitors include Prevacid, Prilosec, generic Omeprazole, Nexium, Aciphex, Protonix, and Xegerid. The medications are best taken ½-hour before breakfast and ½-hour before dinner. Therapy may need to be continued for 6 months or more and some patients may not experience any benefit for several weeks.

#### **Dilation of the PES**

Dilation has proven efficacy for treating PES dysfunction. Dilation is reserved for those individuals with PES dysfunction (stenosis/fibrosis) who still have the ability to elevate the larynx. A PES dilation in an individual with limited pharyngeal strength and poor laryngohyoid elevation is unlikely to result in any improvement and should be avoided. Wang et al. reported their experience with PES dilation in 6 individuals with dysphagia (28). All 6 experienced immediate improvement. Three patients (50%) maintained complete resolution of dysphagia at long-term follow-up (range 8 to 27 months). Solt et al.

performed balloon dilation (to 20mmm) of the PES in 5 individuals (29). All patients experienced improvement symptomatically and on fluoroscopy. There were no complications and only one required re-dilation (mean follow-up of 21 months). These studies suggest that dilation of the PES is a safe and efficacious treatment option for individuals with flow limitation through the PES. Long-term improvement may be realized in some monthsto years after dilation. Dilation of the PES is typically performed with fixed diameter push-type dilators or with radially expanding balloon dilators. Dilators come in diameters of increasing size up to a maximum of 20mm (60 French). Examples of fixed diameter dilators include Maloney bougies and Savary dilators (Figure 16).

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Long-term improvement may be realized in some months-to years after dilation.



Figure 16. An individual undergoing bougie dilation up to 20mm (60F) under general anesthesia.

## **Treating PES Dysfunction**

Savary-type dilators have a central channel that allow for passage over a guide wire. The major advantage of fixed diameter dilators is that they can be sterilized and reused. Balloon dilators are one-time use only and accrue added expense. Balloon dilators expand to specific incremental calibers by pressure injection of saline (Figure 17).



Figure 17. In-office unsedated transnasal balloon dilation of the PES (20mm).

The big advantage of balloon dilation is their ease of use. They allow PES dilation through the nose under direct vision without the need for sedation. The ability to perform unsedated transnasal balloon dilation of the PES in the office without sedation offsets the cost of the disposable dilators. In our experience in-office unsedated transnasal balloon dilation is the safest and most cost efficient way to perform dilation of the PES.

# Chemical denervation of the PES with botulinum toxin type A (BtxA)

BTxA injection into the CP muscle was first introduced by Schneider in 1989 (30). Since that time, several clinicians have reported the efficacy of BTxA in treating disorders of the PES (31-35). BtxA is a purified neurotoxin that binds to receptors on cholinergic nerve terminals. The neurotoxin

is absorbed into the nerve ending, where it inhibits the release of acetylcholine. This results in chemodenervation and reduced muscular contraction (paralysis). The therapeutic affect of BTxA can be appreciated in a few days to weeks after injection. BTxA typically wears off in 3-5 months although some people report prolonged relief of dysphagia years after injection (31). Various techniques are

available to inject BTxA into the CP muscle. The most accurate technique is to inject BTxA into the CP muscle in the operating room under direct vision. A rigid laryngoscope is used to identify and isolate the CP. Twenty to 100 units of BTxA are divided equally and injected into three different locations along the muscle (Figure 18).



Figure 18. Injection of BTxA into the CP muscle under direct vision in the operating room. The patient is under general anesthesia. Twenty units were injected into three different locations (black arrowheads) for a total of 60 units.

Patients who are feeding tube dependent and have "nothing to lose" will usually receive a full 100 units. Patients who are not feeding tube dependent will receive smaller doses (20-60 units) for fear of dispersion of the BTxA into pharyngeal muscles with a worsening of dysphagia. The advantages of BTxA injection in the operating room are its accuracy and the ability to combine the injection with dilation in an already anesthetized and intubated patient. Many patients with PES dysfunction are elderly, malnourished, and infirm. In these individuals, injection of BTxA into the CP may be performed in the office. Office injections of BTxA may be performed under EMG or fluoroscopic guidance. We perform in-office BTxA injections under both EMG and fluoro guidance to provide the most accurate injection (Figures 19 and 20).



Figure 19. Botox injection into the CP under EMG-guidance.







Figure 20. BTxA injection under fluoroscopic guidance.

#### Surgical CP myotomy

Myotomy of the CP muscle is the "gold standard" treatment of PES dysfunction. As with any CP surgery, it is reserved for persons with adequate PES elevation and pharyngeal strength. If the patient's laryngeal elevation and pharyngeal strength are uncertain, it is best to perform a less invasive procedure on the CP first (BTxA injection and/or dilation) to establish treatment efficacy. Surgical myotomy has traditionally been performed through an open cervical incision. Recent advances in endoscopic techniques, however, now allow the clinician to perform a laser-assisted CP myotomy without the need for an open incision. A laryngoscope or distending diverticuloscope is placed through the mouth under general anesthesia. The CP muscle is isolated under the microscope and the CO2 laser is used to divide the muscle. Great care is taken to leave the underlying adventitia intact in order to avoid a post-operative air or saliva leak (Figure 21). Recent data evaluating the endoscopic approach to CP myotomy is promising (36, 37).

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Recent data evaluating the endoscopic approach to CP myotomy is promising.



Figure 21. Endoscopic CP myotomy. a) Surgical exposure isolating the CP muscle. b) The CP muscle has been divided by the C0, laser. The underlying adventitial layer remains intact.

#### Laryngohyoid suspension

Elevation of the larynx and hyoid opens the PES. Surgically suspending the larynx in individuals who cannot elevate on their own appears to be clinically sound. The procedure secures the larynx to the mandible, protects the larynx under the tongue base, and mechanically opens the PES (Figure 22).



Figure 22. Laryngohyoid suspension. The larynx is secured to the hyoid and the laryngohyoid complex is then attached to the mandible. Small arrow = thyroid notch. Large arrow = mandible. H = hyoid.

۲۲ Although the suspension operation is theoretically appealing, it is often unlikely to restore a safe and functional swallow.

Swallowing is a highly coordinated, dynamic process. The laryngohyoid suspension, however, is a static procedure. Patients who cannot elevate their larynx frequently have co-morbid limitations in pharyngeal and lingual peristalsis. Although the suspension operation is theoretically appealing, it is often unlikely to restore a safe and functional swallow. In reality, the procedure has few indications. It is typically reserved for swallowing rehabilitation after partial laryngectomy (38, 39).

## Summary

The PES is a 2.5 to 4.5cm manometric high-pressure zone located between the pharynx and esophagus. It is modifiable with therapy and surgery and thus has tremendous clinical import to dysphagia clinicians. Tools utilized to diagnose PES dysfunction include the bedside swallow evaluation, endoscopy, manometry, and fluoroscopy. Patients with complex swallowing disorders often undergo all diagnostic modalities available. Treatment options available to persons with PES dysfunction include dietary modification, traditional dysphagia therapy, transcutaneous electrical stimulation, anti-reflux medication, dilation, chemical and surgical myotomy, and laryngohyoid suspension. Patients who do best with surgery usually have intact pharyngeal constriction and laryngeal elevation with the swallowing abnormality localized to the PES. We employ a step-up treatment approach beginning with dysphagia therapy and electrical stimulation. We progress to minimally invasive and then invasive surgery as indicated by the individual clinical scenario.

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