Endoscopic CO\textsubscript{2} Laser Cricopharyngeal Myotomy

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Objectives: Over the past 10 years, endoscopic cricopharyngeal myotomy laser surgery has been proposed as an alternative to transcervical cricopharyngeal myotomy. We will describe the technique and review the literature so that it may gain credence as a viable option for the treatment of cricopharyngeal achalasia.

Methods: A literature review of endoscopic and transcervical cricopharyngeal myotomy will be performed. The technical aspects of endoscopic cricopharyngeal myotomy will be presented and accompanied by intraoperative photographs, illustrations, and an online video demonstration.

Results: Endoscopic cricopharyngeal myotomy is a well-tolerated procedure with low morbidity and good outcomes. It can be performed by surgeons who are comfortable with transoral laryngopharyngeal laser surgery.

Conclusions: Endoscopic cricopharyngeal myotomy is a viable alternative to classic transcervical cricopharyngeal myotomy with equivalent outcomes and comparable if not less morbidity.

Key Words: Dysphagia, cricopharyngeal, myotomy, laser surgery, endoscopy.

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INTRODUCTION
Endoscopic cricopharyngeal myotomy (ECPM) was first described in 1994.\textsuperscript{1} Since that time, a number of published series have demonstrated that it is a safe and effective procedure with decreased anesthesia time and morbidity compared with the more traditional transcervical cricopharyngeal myotomy (TCPM). Despite the obvious benefits of ECPM, the procedure has yet to be popularized due to apprehension of learning this new technique and for fears of mediastinitis.\textsuperscript{2,3} Here, we hope to elucidate the benefits and safety of this approach through a literature review and a detailed demonstration of the procedure via intraoperative photographs, illustrations, and an online video demonstration.

METHODS/RESULTS
The ECPM technique involves postcricoid placement of a diverticuloscope. A nasogastric tube may be placed in the esophagus to help identify the esophageal introitus and guide placement of the diverticuloscope (Fig. 1). Visualization of the cricopharyngeus (CP) is aided by pressure of the scope on the surrounding tissues. The anterior flange of the diverticuloscope approaches the esophageal introitus, and the posterior flange abuts the posterior pharyngeal wall highlighting the CP (Fig. 2). The mucosa-covered CP is easily identified as the mound of tissue just proximal to the esophageal introitus (Fig. 3). Once the CP is well exposed and the scope is suspended, the nasogastric tube is removed. The CP is palpated to obtain a sense of its mass and depth. A transmucosal vertical midline incision is then made with a CO\textsubscript{2} laser set in continuous wave mode at a power of 4 to 6 watts mechanically pulsed at 0.1 seconds on and 0.3 seconds off (Figs. 4 and 5). As one gains experience, the majority of the procedure is performed in a nonpulsed fashion for increased efficiency. The overlying mucosa is surprisingly thick. There is a plane between the mucosa and CP, which allows retraction of the incised mucosa and improves exposure of the underlying muscle (Fig. 6). The mucosal incision should completely transect the overlying mucosa, exposing a substantial amount of the CP prior to incising the CP in a vertical midline fashion. As the muscle is transected with the laser, there is lateral retraction of visible muscle fibers (Fig. 7). As a result, the muscle is very easy to discern from the overlying mucosa. The excellent visualization and pulsed laser mode makes it easy to ensure transection of every fiber of the CP without damage to the underlying buccopharyngeal fascia (BPF).

If nonpulsed mode is being used to expedite the procedure, then mechanical pulsing is initiated as the BPF is approached, before it is exposed. The pulsing utilizes the properties of thermal relaxation to minimize unintended peripheral damage due to the laser. In addition, it allows more precise control of the laser. Considering the importance of the inferior pharyngeal constrictor (IPC) in the function of the upper esophageal sphincter (UES), some promote including transection of its inferior aspect.\textsuperscript{4} After complete transection of the CP, repositioning the diverticuloscope proximally allows for this to be performed. If hemostasis beyond the capabilities of a CO\textsubscript{2} laser is needed during the procedure, a neuropledget soaked with 1:10,000 of epinephrine will stop most bleeding while suction cautery is occasionally necessary.

Following transection of the muscle fibers of the CP, the intact BPF is nearly always visible as a contiguous translucent sheet overlying the areolar tissue of the retropharyngeal space.
(RPS) (patient B in Fig. 8). However, this layer is not consistent. Figure 9, which was extracted from the surgical video, is an example of a patient (patient A) where the BPF is extremely thin to nonexistent. The areolar tissue of the retropharyngeal space is immediately encountered after CP transection. Despite the presence or absence of BPF, the RPS should not be disturbed and the alar fascia should never be violated. Disruption of these tissue barriers will substantially increase the risk of mediastinitis. At the completion of the procedure, the mucosa, completely transected CP, BPF, and underlying areolar tissue of the RPS are easily discernible (Fig. 10).

As seen in Figures 8 and 9, the RPS is not empty but filled with areolar tissue. As a result, as demonstrated by patient A, early postoperative gastrograffin swallow, gross pharyngeal contents should be confined to the area directly involved in the surgery even when the buccopharyngeal fascia is not present or has been minimally disrupted (Fig. 11). As is seen in this figure, although gross pharyngeal contents are contained, air may still track through the RPS. It should be noted that as with patient B, when the BPF is present and undamaged, there is no leakage of air into the RPS (Fig. 12). Hence, we recommend avoiding positive pressure ventilation at the end of the surgery, especially in the absence of BPF or if the fascia has been inadvertently violated. Some authors recommend sealing the surgical site with fibrin glue. This does not appear to be necessary unless the BPF has been violated.

As with TCPM, there is a wide array of postoperative protocols as to timing of postoperative swallow studies, length of hospital stay, time to oral feeding, and advancement of diet. No convincing studies exist that evaluate the optimal protocol. We place patients on Ampicillin/Sulbactam and perform a gastrograffin swallow on the morning of postoperative day 1. If no leak is noted, then patients begin a clear liquid diet. If the diet is tolerated and no complications arise, the patient will be discharged home that evening on Amoxicillin/Clavulanic acid elixir for 5 days. The patients will advance to full liquids on postoperative day 3 and then maintain a soft diet from postoperative days 6 to 14. A postoperative esophagram is obtained at 6 weeks (Fig. 13).

**DISCUSSION**

The symptoms of CP achalasia are well known but relatively nonspecific. Patients may complain of progressive dysphagia to solids and occasionally liquids. There
may also may be a globus sensation or in severe cases gross aspiration due to bolus overflow from the hypopharynx when it is prevented from passing the upper esophageal sphincter. When symptoms are severe, patients often become afraid of eating or physically cannot eat enough to obtain sufficient calories. Weight loss ensues as well as the morbidity that accompanies the resultant malnutrition.

The UES is comprised posteriorly of the CP as well as contributions from the IPC. Anteriorly, the UES is made up of the cricoid and arytenoid cartilages. The UES corresponds to a 2–4 cm high pressure zone inferior to the laryngeal opening extending to the inferior border of the cricoid cartilage. Opening of the UES is successful by both the relaxation of the CP and the anterosuperior displacement of the laryngeal framework from the contraction of the suprahyoid musculature. The above processes in conjunction with adequate tongue and pharyngeal propulsion of food bolus are essential to a successful swallow.

The CP is crescent shaped with attachments to the lateral ends of the cricoid cartilage, while the ICP inserts onto a midline raphe. Both the CP and IPC are composed of an outer layer of fast-twitch type I myosin heavy chain (MHC) muscle fibers and an inner layer of slow-twitch type II MHC muscle fibers. The type II fibers are felt to be most responsible for sustained muscle contraction and are the predominant fiber type in both these muscles, more so in the CP. Considering the slinglike insertion of the CP and its predominance of type II fibers, it is hypothesized that the CP is most responsible for the resting sphincteric closure of the UES.

Dysfunction of the CP is from anatomic, neurologic, iatrogenic, inflammatory, neoplastic, or idiopathic causes, and can lead to significant globus sensation, dysphagia, aspiration, a Zenker’s diverticulum, and associated morbidities. There is no gold standard diagnostic test for dysfunction of the CP. Most commonly, a diagnosis is based on findings of postcricoid pooling on flexible laryngoscopic examination and abnormalities on videofluoroscopy; however, videofluoroscopy is largely subjective and postcricoid pooling is nonspecific. On fluoroscopy, CP dysfunction is assumed if there is obstruction of the bolus or if >50% of the lumen is obstructed by a criopharyngeal bar (Fig. 13). Manometry has also been used to diagnose CP dysfunction. Elevated resting UES

Fig. 3. The cricopharyngeus (CP) mound is just proximal to the esophageal introitus.

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Fig. 4. Initial mucosal incision.

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pressure has been suggested as an indicator of UES dysfunction. Unfortunately, this study is complicated by multiple technical and physiologic issues. The resting pressure of the UES changes with multiple physiologic factors as well as with different catheters used. Research has also revealed substantial inter- and intra-subject variability. As a result, no consensus exists on the normal range of resting UES pressure.\(^{11,12}\)

Probably the best evaluation of UES function is with intrabolus manofluorography. Manometry is performed under videofluoroscopy to verify the position of the manometric sensors and allow quantitative analysis of intrabolus pressures in the pharyngoesophageal segment. Using this technique and calculating a mid-intrabolus pressure gradient appears to be a useful and reproducible measurement to identify UES dysfunction, although further study is necessary.\(^{13}\) Unfortunately, this technique is not widely available.

Other diagnostic techniques include electromyography aimed at capturing dyskinesia of the CP and IPC\(^{14}\) or botox injection of the CP. Botox injections can be administered under general anesthesia via direct laryngoscopy, in the office transorally under endoscopic guidance, or transcervically via EMG guidance. These injections can be both diagnostic and temporarily therapeutic.\(^5\) If the injection is helpful, then it is likely that a myotomy will also be helpful. If the injection does not lead to improvement, the significance is unclear. Zaninotto et al.\(^{15}\) had a 72.7% success rate with CP myotomy for patients who did not respond to botox injection. It is important to note that one death from aspiration due to botox injection of the CP has been reported.\(^{13}\) This was likely secondary to increased dysphagia from paresis of the inferior constrictor muscle due to diffusion of the botox.

Based on the above studies, treatment is indicated for patients with defective CP relaxation and adequate oral and pharyngeal propulsion and laryngeal elevation. Practically speaking, though not optimal, most decisions are based on flexible laryngoscopic examination as well as videofluoroscopy. More controversial are patients with normal anatomic and functional studies but clinically evident dysphagia. It remains unclear which of these patients would benefit from myotomy. Unfortunately, our diagnostic armamentarium does not allow us to accurately diagnose all patients, so some are treated on clinical suspicion with mixed success. This should only be done with much trepidation and patient education.

The traditional surgical treatment for UES dysfunction involves cricopharyngeal myotomy using a transcervical approach.\(^{16–18}\) An open approach, while effective, carries surgical morbidity including possible pharyngocutaneous fistula, recurrent laryngeal nerve paralysis, hematoma, seroma, and wound infection.\(^{19,20}\) In 1994, endoscopic cricopharyngeal myotomy was developed by utilizing direct laryngoscopy with laser incision of the CP with a KTP laser.\(^{1,21}\) Soon after, CO\(_2\) laser was employed and has become the laser of choice due to its ability to coagulate small vessels and minimize unintended spread of thermal damage.\(^{22,23}\)

In reviewing the literature, it is apparent that complications from either ECPM or TCPM are few. Assessing complications from TCPM alone proves
difficult because few series address only TCPM while excluding patients with a Zenker’s diverticulum. Studies that focus on ECPM are few in number and all have relatively small sample sizes (Table I). Even in these studies, the etiology underlying CP dysfunction and presence or absence of concomitant oropharyngeal dysphagia varies dramatically. As a result, there are multiple confounding factors that make interstudy comparison difficult. Additionally, for both ECPM and TCPM studies, preoperative diagnostic criteria differ significantly depending on institution, and postoperative measures are equally as diverse.

Brigand et al.\textsuperscript{19} examined a large series of patients with dysphagia. One subset included individuals who underwent TCPM for dysphagia secondary to muscular dystrophy. They performed TCPM on 139 patients and recorded 28 complications in 16 patients (11.5%) in addition to four mortalities (2.9%), which were all related to pulmonary infections. Complications included 12 mucosal breaks (8.6%), eight pulmonary infections (5.8%), two hematomas (1.4%), and one wound infection, fistula, buccal floor infection, pulmonary embolism, hypertensive crisis, and stroke (0.7%). The authors of this study cite a 75% improvement in oropharyngeal dysphagia symptoms for patients undergoing TCPM; however, there is no reference to any objective or subjective measure. Similarly, in a series of 54 patients who underwent TCPM, Mckenna and Dedo\textsuperscript{16} cite normal postoperative swallowing in 45% and improved swallowing in an additional 30%, in a group that had a surgical complication rate of just 3.7%.

Ross et al.,\textsuperscript{20} in a series of 33 TCPM, divided their patients into three categories including head and neck surgical patients (n = 13), neurosurgical patients (n = 9), and patients with primary neurogenic disorders (n = 11). Outcomes were measured by tolerance of oral intake and dysphagia symptoms. They were stratified as excellent (resumption of full diet and disappearance of aspiration), good (maintenance on some form of oral feeding with minimal dysphagia), or poor (persistent aspiration of food and secretions). The best results were seen in the primary neurogenic group with 8/11 patients categorized as excellent surgical outcome, 1/11 as good surgical outcome, and 2/11 as poor surgical outcome. The worst-performing group was the neurosurgical group.

![Fig. 7. The cricopharyngeus (CP) muscle fibers retract laterally with each laser pulse. They are easily discernible from the mucosa and underlying fascia.](image)

![Fig. 8. Intact buccopharyngeal fascia after complete transection of the cricopharyngeus muscle.](image)
with 6/9 patients having a poor surgical outcome, 1/9 good, and 2/9 excellent. Four (12%) complications were noted including one wound infection, one aspiration pneumonia, one transient vocal fold paresis, and one mortality secondary to staphylococcal pneumonia.

Dauer et al.\textsuperscript{3} compared the Mayo experience of TCPM ($n = 8$) vs. ECPM ($n = 14$) from 1996 to 2003. Preoperative evaluation of swallowing was measured with the “Functional Outcome Swallowing Scale.” While preoperative and postoperative swallowing was worse in the TCPM group, mean improvement was equal between groups. Mean hospital stay was shorter for the endoscopic group (1.2 vs. 4.4 days) as was median operative time (29 vs. 87 minutes). However, this was at least partially attributed to the need for additional procedures for the TCPM group (laryngo hyoid suspension 3/8 and muscle biopsy 1/8). Complications in the ECPM group included two patients with fever of unknown origin and one self-limited episode of chest pain as opposed to the TCPM group, which included one individual with chest pain, one prolonged intubation, and one pharyngocutaneous fistula. There were no incidences of mediastinitis.

Other series of ECPM report few complications and good functional outcomes. Takes et al.,\textsuperscript{24} in a series of 10 patients, reported no major complications, free air in soft tissue on X-ray in four patients, and subcutaneous emphysema in one patient. If postoperative day 1 X-ray showed no free air, an oral diet was started. In the presence of free air on day 1, oral intake was started on postoperative day 3. As measured by a questionnaire at three months, all subjects improved postoperatively, but not all were symptom free. One patient required a revision procedure secondary to fibrosis at the surgical site.

Brondbo,\textsuperscript{4} in a series of 17 patients, reported no complications related to ECPM, and subjective swallowing improved in all but one patient. A soft diet was resumed on postoperative day 3. Similarly, Lawson et al.,\textsuperscript{14} in a series of 29 patients, reported no complications and near universal improvements in subjective evaluation of dysphagia and aspiration as well as objective variables as measured by flexible laryngoscopic evaluation and

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Fig. 9. In patient A, the buccopharyngeal fascia (BPF) was extremely thin to nonexistent, and the areolar tissue of the retropharyngeal space (RPS) is immediately encountered upon complete transection of the cricopharyngeus (CP).

Fig. 10. At the completion of the procedure, the mucosa, completely transected cricopharyngeus (CP), buccopharyngeal fascia (BPF), and underlying areolar tissue of the retropharyngeal space (RPS) are easily discernible.
videofluoroscopy. A liquid or soft diet was started on postoperative day 3 following video-fluoroscopy.

Critics of endoscopic myotomy commonly cite risk of mediastinitis secondary to breach of the BPF; however, this complication has not been documented in recent series. A brief discussion of facial planes and potential spaces is important in understanding the potential concerns regarding violation of fascial planes. The fascial plane surrounding the esophagus, CP, and IPC is the BPF, the visceral layer of the middle layer of the deep cervical fascia. Its superior limit is the skull base and inferiorly is continuous with the fibrous pericardium of the mediastinum. Posterior to the BPF is the RPS, which is filled with areolar tissue and defined posteriorly by the AF. The AF is part of the deep layer of the deep cervical fascia, which fuses with the BPF in the superior mediastinum at the level of T1/T2. Posterior to the AF is the danger space (DS), which is defined posteriorly by the prevertebral fascia (PVF). This is a potential space, which runs from the skull base superiorly to the diaphragm inferiorly. Posterior to the PVF is the prevertebral space. Anterior to the vertebral bodies, this is a potential space that runs from the skull base to the coccyx inferiorly. Laterally, the prevertebral muscles are adherent to the transverse processes. Violation of these facial layers clearly can predispose patients to having pharyngeal contents travel extraluminally and cause infection.

In investigation of ECPM and fascial planes, ECPM was performed with CO$_2$ laser on cadaveric specimens. Postoperative dissection revealed an intact BPF layer, which correlates to preservation of the fascial layer protecting spread into the RPS. In addition, as demonstrated in

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**Fig. 11.** Patient A gastrograffin swallow postoperative day 1. Note the containment of contrast by retropharyngeal space (RPS) with minimal tracking of air through the space.

**Fig. 12.** Patient B gastrograffin swallow postoperative day 1. Note the containment of contrast by buccopharyngeal fascia (BPF) in the surgical area. Due to intact BPF, there is no evidence of air entry into the RPS.

**Fig. 13.** (a) Patient A preoperative barium swallow with cricopharyngeal bar. (b) Patient A six-week postoperative gastrograffin swallow. Note the recurrence of the asymptomatic small anterior esophageal web that has recurred despite the dilation immediately prior to the myotomy.
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<tr>
<th></th>
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VFS = videofluoroscopy; MFG = manofluorography; MBS = modified barium swallow; EMG = electromyography; KTP = potassium-titanyl-phosphate laser; NR = not reported; NGT = nasogastric tube; POD = postoperative day; PO = orally; CXR = chest radiograph.
this paper, even when the BPF is minimally violated, gross pharyngeal contents are contained by the undisturbed areolar tissue of the retropharyngeal space.

CP myotomy is not the only treatment option for patients with UES dysfunction. Alternate therapeutic options include intramuscular botox injections\(^5\) and various forms of dilation including bougie or balloon dilation.\(^9\) The above options are associated with recurrence of symptoms and need for repeated procedures. Surgical intervention appears to be a more reliable and lasting intervention for treating UES dysfunction.

**CONCLUSIONS**

When considering surgical treatment for CP dysfunction, ECPM is a safe, reliable, and possibly a more attractive option than TCPM. Either approach for myotomy has relatively low risk of postoperative complication and good functional outcome. The endoscopic approach is favorable considering the reduced surgical time, reduced recovery time, lack of external scar, and lower risk of complication during reoperation after previous TCPM.

As with any new procedure, the acceptance and popularization of the procedure must overcome certain hurdles. First, the procedure must be advantageous when compared with the gold standard. The new procedure should be proven to be safe and efficacious with similar outcomes from multiple surgeons. The results must persist over long-term follow-up. The technique has to be described such that it can be duplicated using the skills already in the armamentarium of a surgeon who wishes to conduct the surgery. Endoscopic cricopharyngeal myotomy has fulfilled all the above criteria except for the description of the surgery. Thus far, descriptions have consisted of minimal text or still photo description. We anticipate that the above review, comprehensive surgical description, intraoperative photographs, illustrations, and supplementary online video demonstration will provide the necessary information to encourage surgeons to consider ECPM as a viable alternative to TCPM.

**BIBLIOGRAPHY**


