Tracheobronchoplasty

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Introduction

Tracheobronchomalacia (TBM) in adults is an acquired condition in which the central airway walls are weakened, resulting in excessive dynamic collapse of the lumen of the trachea and bronchi. Some degree of collapsibility is normal, with nearly three quarters of healthy volunteers exhibiting cross-sectional airway reduction greater than 50 % during maneuvers designed to increase intrathoracic pressures, such as forced expiration or Valsalva. However, severe TBM with complete or near-complete collapse is a pathologic entity that may result in disabling dyspnea, the inability to clear secretions, recurrent respiratory infections, and paroxysmal and frequent coughing. Patients may exhibit one or more of these symptoms. In patients with respiratory failure from exacerbation of chronic respiratory conditions or other causes, TBM occasionally may prevent separation from mechanical ventilation (Gangadharan 2010).

Whereas focal malacia of the airway may be caused by goiter, vascular anomalies, surgical anastomosis of the trachea or bronchi, tracheostomy, or prolonged endotracheal intubation, the etiology of the diffuse acquired form of TBM is often unknown. Mounier-Kuhn syndrome is a rare disease characterized by tracheobronchomegaly and TBM. Relapsing polychondritis also may manifest as TBM, in addition to other stigmata of cartilaginous abnormality. Chronic obstructive pulmonary disease and gastroesophageal reflux are associated with TBM, although no clear causal inferences can be drawn.

Weakening and collapse of the central airways may be propagated by the cartilaginous structures, the membranous wall, or both (Murgu 2007). In pure cartilaginous malacia, which often is seen with tracheomegaly, the cartilaginous–membranous junctions are seen to move laterally apart, creating a flattened cartilaginous arch. The decreased anterior–posterior diameter of the airway creates the dynamic airway narrowing. In contradistinction, with pure membranous wall malacia, the transverse diameter of the airway is preserved but the membranous wall bows into the lumen, thereby decreasing the cross-sectional area (Boiselle 2006). Both these forms of malacia are detected with dynamic CT as well as functional bronchoscopy, in which the evaluations are done with coached forced expiration (Zhang et al. 2003). Intermediate forms having some component of each abnormality may be seen.

Once severe diffuse TBM is diagnosed in patients with significant symptomatology, additional preoperative workup includes full pulmonary function testing and evaluation for gastroesophageal reflux disease with esophageal pH testing. Because patients may have concomitant diseases such as asthma or chronic obstructive lung disease, it is useful to document the potential contribution of these to the overall symptomatology. If significant acid reflux is found, our practice is to perform a laparoscopic fundoplication if the airway disease does not prohibit general anesthesia, as ongoing severe reflux may confound treatment of respiratory symptoms.

The selection of patients for surgical stabilization of TBM begins with a short-term trial of silicone stenting of the trachea and mainstem bronchi (Ernst et al. 2007). Our preferred stent is a Y-stent with a short right-sided limb so the right upper lobe is not obstructed. Patients with dyspnea as their primary symptom should notice a striking improvement while the stent prevents dynamic collapse of the airways. The region of stabilization in the central airways mimics the effects of tracheobronchoplasty (TBP), which will not splint the airway into the lobar or segmental level. If a patient responds well to the stent trial, an assumption is made that external splinting of the same airways should achieve the

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same amelioration, and that central airway disease, as opposed to more distal airway disease or lung parenchymal pathology, is the major cause of the patient's symptoms.

The stent trial should last no longer than 2 weeks, to minimize the risk of a stent-related complication, such as mucus plugging, granulation tissue formation, or tracheitis/bronchitis. It is important to note that the stent trial may yield equivocal or frankly negative results in cases in which cough, recurrent infections, or secretions are the primary symptoms, or in cases in which a stent-related complication ensues and obfuscates the subjective sense of improvement otherwise (Ernst et al. 2007).

Figure 7.1

The patient receives general anesthesia and is intubated with a modified double-lumen endotracheal tube. To facilitate custom resizing of the airway, the tracheal lumen of a double-lumen tube is shaved off with a scalpel before intubation. This procedure allows a very thin tube to be placed within the airway with minimal distention or distortion and avoids using the longer cuff, which might herniate or be pierced by a suture if a single-lumen tube is used and simply advanced to a left mainstem bronchus position. A standard right posterolateral thoracotomy is used. For postoperative analgesia for this incision, an epidural catheter is placed preoperatively. The azygous vein is ligated, and the pleura overlying the posterior membranous trachea is dissected from the thoracic inlet to the mainstem bronchi. Care is taken to avoid damage to the vagus nerves or either recurrent laryngeal nerve during the course of the dissection. Dissection of the lateral walls of the airway also is avoided to preserve the segmental blood supply of the trachea. The right mainstem bronchus and bronchus intermedius are dissected free to the level of the superior segment bronchial takeoff. The left mainstem bronchus is retracted from the mediastinum as dissection continues down to the level of the bifurcation of upper and lower lobes, if possible. Although malacia may predominate in a more localized portion of the airway, most cases requiring TBP are diffuse and severe, requiring this extensive exposure for repair. Following exposure, the transverse diameter is measured at the proximal trachea, distal trachea, mainstem bronchi, and bronchus intermedius

TBP uses a polypropylene Y-shaped mesh to splint the posterior membrane. Unlike the silicone Y-stent, posterior splinting achieves stabilization of the airway without any internal foreign body (Herzog et al. 1987). One key point of the conduct of the operation is an ongoing assessment of the degree of tension used to affix the mesh to the airway wall, as the mesh has some function of drawing the cartilaginous–membranous junctions slightly closer to each other to create some tautness of the posterior membrane—mechanically akin to the tension created by pulling back on a bowstring.

Figure 7.1

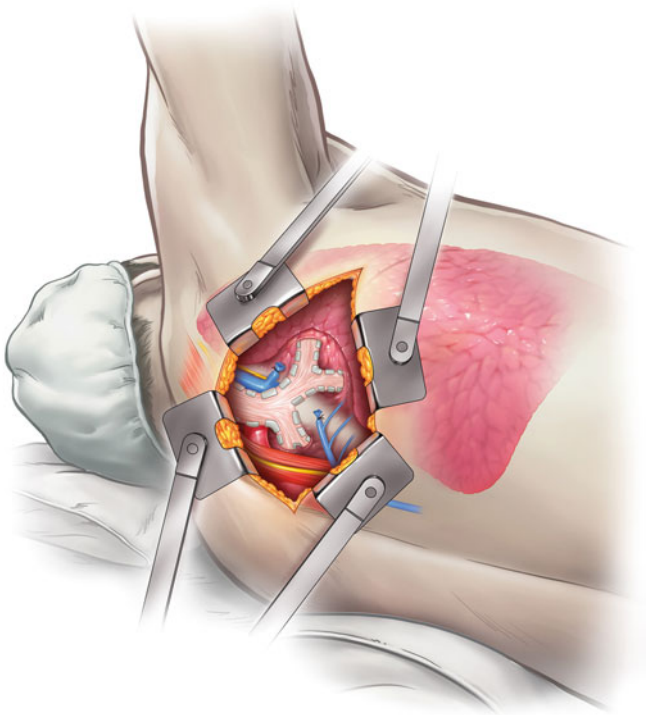


Figure 7.2

The principle of TBP is to stabilize the posterior membrane of the malacic airway with a polypropylene mesh, which is affixed in rows of polypropylene sutures placed in partial-thickness fashion through the airway wall. Airways with malacia ranging from primarily cartilaginous to primarily membranous are all candidates for the procedure. Depending on the degree of cartilaginous bowing of the airways, varying degrees of mesh "cinching" (creation of medial tension on the cartilaginous ends) are used. In general, a 30–40 % reduction in the transverse diameter is achieved, but in small airways with dynamic membranous intrusion alone, much less airway narrowing may be desirable

Figure 7.2

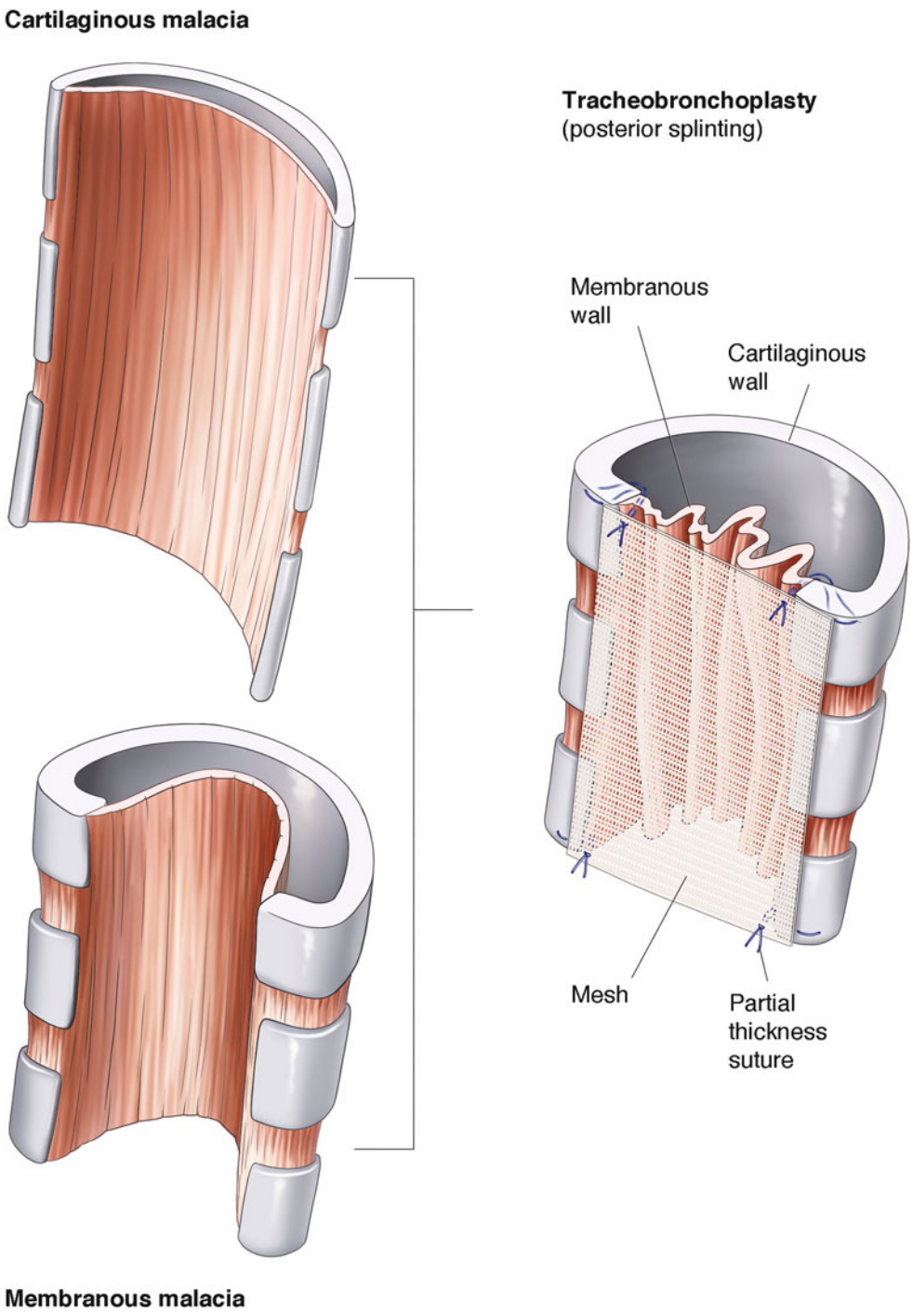

Cartilaginous malacia
Membranous malacia
Tracheobronchoplasty
(posterior splinting)
Membranous wall
Cartilaginous wall
Mesh
Partial thickness suture

Figure 7.3

Although some groups favor the use of three separate pieces of mesh to splint the trachea and bilateral bronchi (Wright et al. 2005), we use a single Y-shaped piece of mesh (Majid et al. 2008). Once the degree of downsizing of the transverse diameter is determined, the mesh is cut with a 0.5-cm border around it to avoid having to suture the very edge of the mesh, which may fray. The initial suture rows are placed in the carinal region in a triangle—one row across the distal trachea, one across the proximal right mainstem bronchus, and one across the proximal left mainstem bronchus—and a single suture is placed in the membranous wall in the center of this triangle. Rows of four sutures are used, with the two lateral sutures placed in the cartilaginous–membranous junctions and the two membranous wall sutures placed one third and two thirds the way across the membranous wall. The sutures are placed in partial-thickness mattress fashion, with each row's sutures placed in order from one cartilaginous–membranous junction to the two membranous wall sutures to the contralateral cartilaginous–membranous junction so that minor adjustments in spacing may be made from row to row. Once the carinal triangle is completed, the mesh is parachuted into place and the sutures of each row are tied, first the cartilaginous–membranous sutures of each side then the two membranous wall sutures. Suture placement near the endotracheal tube balloon is facilitated by periods of apnea and partial withdrawal of the tube

Figure 7.3

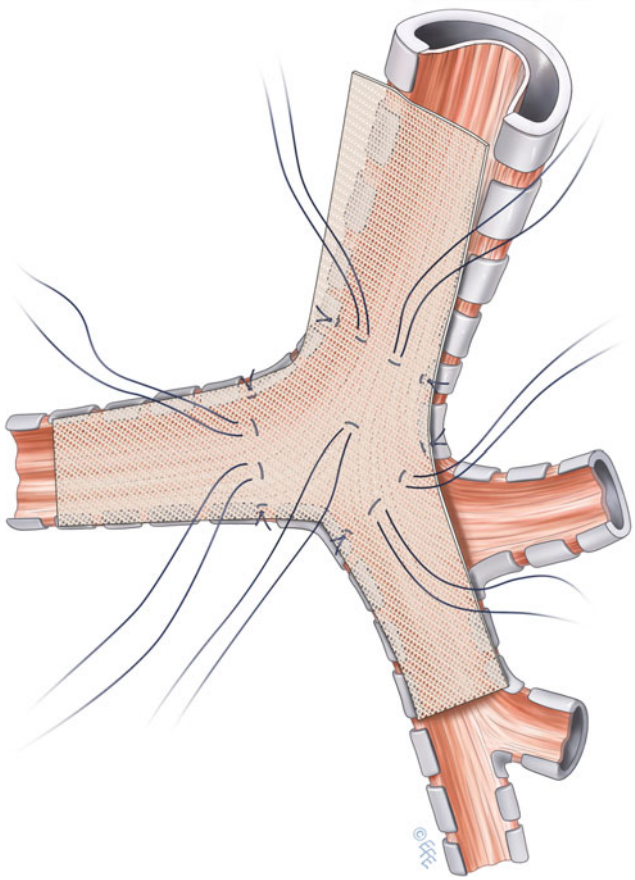
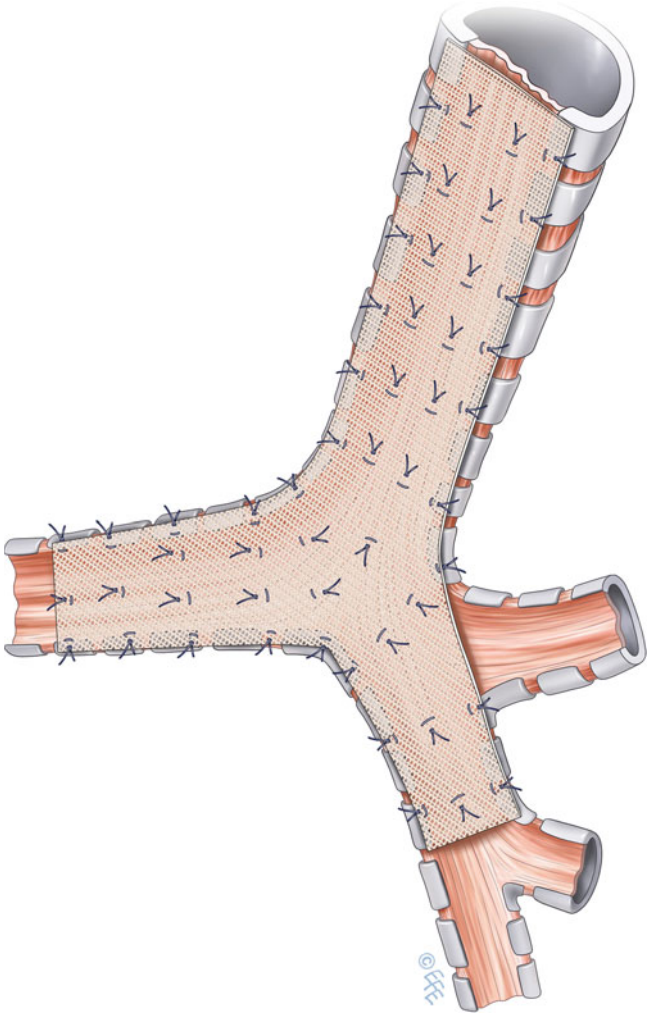


Figure 7.4

With the mesh affixed to the carinal triangle, the tracheal splinting is completed, with the rows progressing distally to proximally on the airway. Each row is spaced 5–7 mm from the last as the entire thoracic trachea is stabilized, all the way up to the inlet. One centimeter of extra mesh is tucked into the inlet above the level of the highest row of sutures. The right mainstem bronchus and bronchus intermedius are completed next. As the airway narrows distally, rows of three sutures may be used. Excessive narrowing of the smaller airways is avoided. In addition, undue axial compression at the level of the right upper lobe takeoff must be avoided so that the lobar orifice is not obstructed. The left mainstem bronchus requires careful retraction of the esophagus posteriorly and rightward retraction of the airway to allow the splinting to continue to the distal aspect of the bronchus. At the completion of the procedure, but prior to chest closure, bronchoscopy is performed to assess the appearance of the repair and assure that no obstruction was created. It is normal to see some bulging or quilting of the membranous wall as the redundancy is taken up by the mesh. If inadvertently intraluminal sutures are detected, they may be removed at this time to prevent contamination of the mesh from bacteria tracking extraluminally along the suture. The chest is irrigated and the airway inspected for any sign of air leak. A chest drain is placed, and the thoracotomy is closed in the standard fashion (Gangadharan et al. 2011)

Figure 7.4



Conclusion

TBP for severe diffuse TBM is shown to be very effective for alleviating symptoms in properly selected patients. Despite the arduous and invasive operation, most patients can be discharged home as opposed to a rehabilitation facility. The overall intensive care unit stay is around 3 days, and the hospital length of stay averages 8 days. Mortality risk is in the 2–3 % range. Most patients (>80 %) will report dramatic subjective relief of their symptoms, and functional testing with 6-min walk duration will corroborate these findings (Gangadharan et al. 2011).

The importance of patient selection cannot be understated, as the specificity of the symptom complex associated with TBM is extremely low. Competing comorbidities may abrogate the benefit of TBP, so the stent trial is extremely important as a basic screening tool to determine candidacy for surgical correction (Majid et al. 2008). However, there is not yet an objective outcome proven to improve following TBP or stenting. Forced expiratory volume in 1 s (FEV_1), for example, has not been shown to increase with either internal stabilization via stenting or external stabilization with surgery. Although there are parallels to the experience with lung volume reduction surgery and functional and subjective outcomes, the specter of the placebo effect with stenting and surgery certainly must be considered with any potential TBM patient. To minimize inappropriate patient selection, it is incumbent on the surgeon to determine the true effects of internal stabilization—whether the patient was able to perform discrete aerobic tasks previously inaccessible to him or her, such as completing a shopping trip without stopping for dyspnea.

The surgeon's judgment is also crucially important to identify the patients in whom a stent trial may not be appropriate. Patients with extreme tracheomegaly may not be able to be fitted with an appropriately sized stent. Other patients whose primary debilitating symptom is paroxysmal barking coughing may not perceive benefit from a stent, as this foreign body itself may exacerbate coughing. Similarly, if recurrent infections are the hallmark of the patient's TBM, a stent trial is unlikely to shed any light on whether airway stabilization will reduce or eliminate the frequency of infections. In these cases, one must assess the severity of anatomic derangement in light of the symptoms.

Overall complication profiles for this operation are very good. Despite the severity of respiratory symptoms and comorbidities in the TBM patient cohort, only a few patients will need intermediate or long-term ventilator management postoperatively. Although recurrence rates requiring reintervention are low, the patient's malacia may progress into the (nonrepaired) cervical trachea, requiring subsequent repair via resection and reconstruction. Because of the potential for disease progression, complete repair of the thoracic central airways is preferred over partial splinting (i.e., splinting of only the thoracic trachea or one mainstem bronchus).

Finally, the optimum approach to these complex patients involves close coordination of services provided by thoracic surgeons, interventional pulmonologists, and chest radiologists. From the establishment of the diagnosis with endoscopic and radiographic means, to the trial of airway stabilization, to the postoperative assessments and maintenance of airway patency in the short and long term, a multidisciplinary team provides the most comprehensive care. For patients in whom TBM is drastically altering quality of life, TBP should markedly improve their well-being.

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