Chapter 70 – Management of Tracheal Stenosis

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Tracheal stenosis is a rare condition that may arise from a variety of causes, including congenital conditions, iatrogenic and accidental trauma, autoimmune diseases, infections, and neoplasms. Its pathogenesis includes injury to the tracheal lining or its cartilaginous framework resulting in scarring and loss of support, with subsequent collapse of the airway and stenosis. The laryngotracheal cartilaginous framework depends on its perichondrium for blood supply. Ischemic cartilage loses its mechanical integrity and collapses, thereby leading to a functional stenosis. Furthermore, exposed cartilage deprived of its blood supply necroses rapidly and acts as a foreign body; the ensuing inflamma-tory reaction causes further tissue destruction and scarring.

An in-depth discussion of the pathogenesis of laryngotracheal stenosis is beyond the scope of this chapter. The following includes a brief discussion of the most significant etiologic factors.

PATIENT SELECTION

External Trauma

The laryngotracheal complex is protected by the mandible, the sternum, and the flexion mechanism of the neck. However, civilian violence, motor vehicle accidents, and sports injuries have led to an increase in the frequency of post-traumatic laryngotracheal stenosis. The incidence of laryngotracheal stenosis after external trauma varies from 0% to 59%. Even when adequate and immediate repair is accomplished, traumatic disruption of supporting structures, loss of mucoperichondrium, or laryngotracheal separation is usually accompanied by some degree of airway narrowing.[1]

Endotracheal Intubation

The incidence of laryngotracheal stenosis after prolonged or repeated endotracheal intubation ranges from 3% to 8% in both adults and children.[2,3] An incidence as high as 44% has been cited for low-birthweight neonates and those with respiratory distress syndrome.[2–4] Earlier endoscopy and tracheotomy in low-birthweight infants and other high-risk groups may reduce the risk of intubation-related laryngotracheal stenosis in these patients.[4]

Multiple factors play a role in the etiology of laryngotracheal stenosis after endotracheal intubation. Time of intubation, size of the tube, pressure and friction by the shaft or cuff, repeated intubation, foreign body reaction to the tube, release of toxic substances used for sterilization, use of a stylet, route of intubation (nasal or orotracheal), techniques for nursing care (suctioning, fixation), and anatomic differences between the genders are among many important factors that can be correlated with the development of postintubation stenosis.

Nordin and Lindholm,[5] using a rabbit model, correlated the degree of damage with time of intubation and with characteristics of the cuff of the endotracheal tube. They concluded that the pressure exerted by the cuff over the tracheal tissues is more important than the duration of intubation. Because microcirculation of the laryngeal mucosa stops at a pressure of 30 mm Hg, a low-volume, high-pressure cuff is more likely to cause an ischemic injury than a high-volume, low-pressure cuff is. Nonetheless, an overinflated, high-volume cuff can stop the microcirculation and produce the same injury as a low-volume cuff.

Whited,[6] in a dog model, demonstrated how the biomechanics of endotracheal tubes produces ulceration of the posterior glottis and circumferential injury of the subglottis and trachea. Whited[7] confirmed the findings of his animal study in a clinical prospective study that correlated the degree of injury with patterns and length of intubation. Patients who were intubated endotracheally for 2 to 5 days had a 0% to 2% incidence of chronic laryngotracheal stenosis, those intubated for 5 to 10 days had a 4% to 5% incidence, and those intubated for more than 10 days had a 12% to 14% incidence. He suggested that a tracheotomy may prevent laryngotracheal stenosis in patients who need endotracheal intubation for more than 10 days. It should be remembered, however, that the type of tracheotomy incision and biomechanical factors related to the tracheotomy tube also contribute to the development of stenosis.

Bryce[8] also correlated the time of intubation with laryngeal injuries. Lesions caused by repeated intubation were the most severe. His findings suggested that perichondritis is the most significant factor for the development of stenosis.

Age is another important factor influencing the site and degree of stenosis. Neonates show a predisposition for subglottic involvement,[2] whereas adults are more prone to scarring in the posterior commissure.[3,6] Nevertheless, combined stenoses account for about one third of all laryngeal stenoses at any age.

Infectious, Autoimmune, and Granulomatous Diseases

Tuberculosis, histoplasmosis, blastomycosis, leprosy, and syphilis are endemic in several areas of the world. They share a common phase of erythema and edema that progresses to chondritis, necrosis, and scarring.[9] Diseases such as relapsing polychondritis and Wegener's granulomatosis may destroy the cartilaginous framework and thereby lead to collapse of the airway. Subglottic stenosis occurs in 10% to 20% of patients with Wegener's granulomatosis, and the mainstay of treatment remains medical (e.g., cyclophosphamide, steroids). Surgical therapy, which usually consists of dilatation and adjuvant modalities such as injectable steroids and topical mitomycin C, is typically reserved for those who have failed medical treatment and is used only during disease remission.[10,11]

Gastropharyngeal Reflux

Repeated exposure to pepsin and acid (i.e., gastric refluxate) produces mucosal and submucosal injuries leading to scarring.[12] Patients with laryngotracheal stenosis and those at risk for the development of stenosis should be carefully monitored for gastroesophageal and gastropharyngeal reflux or be treated empirically with proton pump inhibitors or high dose H_2-blockers. Patients with recurrent or persistent laryngotracheal stenosis must be assumed to have gastroesophageal reflux and be treated accordingly.

PATIENT EVALUATION

Clinical Evaluation

The degree of dysfunction and therefore the clinical manifestations of tracheal stenosis vary widely. Patients with tracheal stenosis may complain of shortness of breath, dyspnea on exertion, stridor, hoarseness, dysphagia, aspiration, difficulty clearing secretions, or any combination of these symptoms and signs. Children often have a history of recurrent croup or cardiopulmonary problems.

In an office setting, flexible fiberoptic laryngoscopy is essential to evaluate the site and degree of the stenosis, as well as vocal fold mobility. In a retrospective review of pediatric cricotracheal resection, a multivariate analysis revealed that unilateral or bilateral vocal fold immobility was the only significant risk factor for failure of decannulation after airway reconstruction.[13] Video laryngoscopy and still photographs provide objective documentation that can be discussed with the patient and reviewed by other laryngologists (Fig. 70-1). Administration of topical lidocaine instilled over the glottis or by nebulization allows the endoscope to pass through the glottis for visualization of the proximal part of the trachea. This provides a good estimate of the degree of stenosis but frequently may not be adequate to ascertain the length of the narrowing because of an inability to pass the scope through the entire length of the stenotic segment. Passage of the scope through a tight stenosis (>50% or higher than grade 2 in the Cotton classification) is not recommended in the office setting. Instrumentation of the airway may lead to further iatrogenic narrowing and a potentially unstable airway.

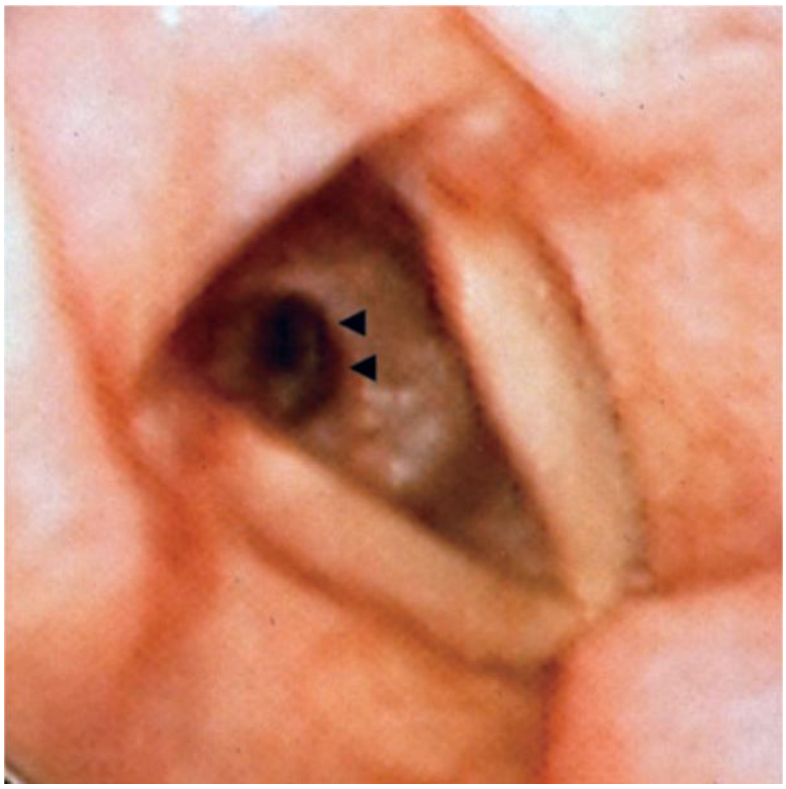

Figure 70-1 Flexible laryngoscopy demonstrating stenosis of the subglottis and proximal part of the trachea (*arrowheads*).

Direct laryngoscopy and rigid bronchoscopy using rod-lens telescopes with the patient under general anesthesia complement the office examination. Endoscopic methods of quantifying the extent and severity of the stenosis, as well as monitoring the success of treatment, have been reported.[14] Caretta and associates[15] compared preoperative findings on endoscopy and computed tomography (CT) with the intraoperative findings of 12 patients who underwent airway reconstruction. They found that rigid endoscopy remains the most reliable tool for accurately assessing the length, extent, and location of stenosis preoperatively. Tracheomalacia can be diagnosed if the endoscopy is performed with the patient breathing spontaneously.

Noninvasive methods of improving the diagnosis and monitoring patients with airway stenosis are available and have a promising future; however, their practical role in the clinical setting remains unclear. Nouraei and coworkers[16] developed and tested a model based on flow-volume loops that can be used to quantify the mechanical extent and the clinical impact of laryngotracheal stenosis.

Imaging

Xeroradiography provides exquisite definition of the mucosal surface; however, this technique requires greater radiation exposure and is not commonly available or used in the United States. In small children, soft tissue radiographs may be sufficient to localize and grade the stenosis. Fluoroscopy is most helpful to evaluate areas of tracheomalacia that collapse on inspiration.

CT better ascertains the integrity of the cartilaginous framework. Spiral CT with three-dimensional reconstruction allows evaluation of the extent, shape, and site of the stenosis (Fig. 70-2). During spiral CT the patient is moved through the scanner gantry at a constant rate, thus scanning continuously during a single breath hold. This avoids artifacts introduced when the imaging data are acquired during multiple breaths. Three-dimensional reconstruction allows the possibility of "virtual" endoscopy.[17]

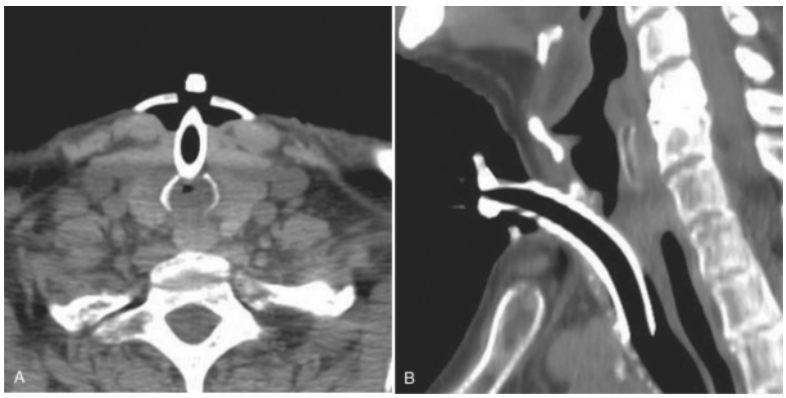

Figure 70-2 Axial (**A**) and sagittal (**B**) computed tomography scans (soft tissue algorithm) in a patient with laryngotracheal stenosis. The tracheotomy is entering the airway just distal to the stenotic segment.

Magnetic resonance imaging (MRI) is useful in the evaluation of extensive laryngotracheal stenosis and does not involve any radiation exposure. MRI allows direct imaging in the sagittal and coronal planes, which may be useful for planning treatment. A major limitation, however, is that the patient must lie flat and still for a long time. This is not tolerated well by children or by most adults with significant tracheal stenosis. In addition, MRI artifacts are created by cardiac and respiratory movements. Ultrasound may also provide a convenient, well-tolerated, noninvasive method of assessing the diameter of the subglottic airway.[18]

SURGICAL TECHNIQUES

Securing the airway is the cornerstone of all procedures for correction of laryngotracheal stenosis. Intraoperatively, the airway may be secured with an endotra-cheal tube, rigid bronchoscopy, jet ventilation, or a tracheotomy.

Transoral or transnasal endotracheal intubation is possible in patients who can be ventilated by mask or in those with a stenosis that can be quickly dilated to allow safe intubation. Patients who have a thin laryngotracheal web are amenable to transendoscopic procedures that will require minimal surgical manipulation (i.e., less probability for postoperative edema) and may therefore be intubated preoperatively. A tracheotomy performed under local anesthesia is recommended for patients who have significant airway compromise.

The tracheotomy should be performed in an area that will not compromise the surgical procedure. We prefer to incise the trachea at the level of the stenosis, thus sparing the normal trachea from another injury. Usually, this segment will be resected as part of the reconstructive surgery.

Jet-pressure ventilation (e.g., a Venturi system) is usually ill advised because the stenosis implies restricted outflow that may lead to tension pneumothorax. In select patients, however, the stenosis can be bypassed and outflow guaranteed with a rigid bronchoscope.

Gentle handling of tissues during surgery is fundamental in preventing postoperative edema and compromise of the airway. The use of systemic corticosteroids in the perioperative period, although their benefit is scientifically unproved, may help minimize the edema. In addition, depot corticosteroids can be injected via a laryngeal injector or a no. 22 butterfly needle with 12-inch tubing before dilatation. The dilatation is then performed in sequential fashion. Corticosteroids prevent intracellular sequestration and stabilize cell membranes, thereby preventing the release of lysosomes that produce swelling and tissue destruction. They also inhibit collagen synthesis, enhance collagen breakdown, and reduce mitosis and the active transport of fibroblasts. Empirically, intralesional injections may be of benefit to soften scar bands and synechiae.

Laryngotracheal surgery is classified as a clean-contaminated procedure, for which perioperative prophylactic administration of antibiotics is recommended. A prolonged therapeutic course of antibiotics may be indicated for active chondritis. The theoretical value of a prolonged course of antibiotics is to control infection, thus stopping a vicious circle of chondritis, necrosis, formation of granulation tissue, and scar deposition.

The diversity of surgical techniques is matched only by the imagination of the surgeons dealing with laryngotracheal stenosis. Treatment of laryngeal stenosis has evolved from a “wait-and-see” philosophy to a proactive approach that includes tracheotomy, dilatation, endoscopic procedures with microsurgery, and transcervical approaches with single or multistaged reconstruction. In an attempt to improve the outcome, surgery has been combined with the use of antibiotics, stents, and corticosteroids. Unfortunately, none of these surgical techniques, singly or in combination, offers a 100% rate of decannulation.

It should be noted that clinical studies addressing different therapeutic options are limited by their retrospective, nonrandomized natures and by the lack of standard definitions. Reports on the use of different surgical methods and ancillary procedures, such as stenting and steroids, have led to reports with opposite findings and conclusions.

Dilatation

Dilatation is most successful when used in patients with thin, congenital webs. Acquired stenosis shows hyalinization of connective tissue and collagen cross-linking that commonly translate into an incompressible, rigid scar. Thus, acquired stenosis generally implies a more severe stenosis that resists dilatation.

However, the success rate of dilatation for acquired stenosis improves when the technique is used for soft or immature scars of minimal thickness and those associated with Wegener's granulomatosis[19] and when it is used as an adjunct to other techniques (e.g., laser surgery).[20] In addition, dilatation is useful in avoiding a tracheostomy in patients with a stenosis that has not “matured” or to prepare the lumen before tracheal stenting.[21] It may offer palliation to patients in poor general medical condition. A significant disadvantage of the technique is the frequent need for repeated dilatation. Overall, in approximately three quarters of patients treated with dilatation as primary therapy, the stenosis will recur and require a subsequent intervention.[22,23]

We prefer to dilate with an expandable balloon (CRE, Boston Medical) under full visualization via suspension laryngoscopy.[21] The patient can be intubated or a bronchoscope can be introduced into the trachea through a suspended laryngoscope (e.g., Dedo laryngoscope), thus maintaining a secure airway throughout surgery.

Stenting

Technologic advances have allowed the design of stents that can be inserted with relative simplicity and reliability.[24] The most popular stents are those made of silicone (e.g., Dumon, Montgomery) or expandable metallic mesh. Silicone stents provide palliation of airway obstruction but interfere with normal mucociliary clearance and may become obstructed with secretions. Other problems associated with silicone stents include migration, malposition, and the formation of granulation tissue. Metallic stents made of various alloys have been used for the long-term treatment of tracheal stenosis secondary to acquired scarring, loss of tissue, and malignancy. These stents include the Palmaz and Gianturco made of stainless steel, the Wallstent made of cobalt, and the Strecker and Ultraflex made of titanium or nitinol. Metallic stents are expanded by balloon dilatation or by inherent recoil. Those that expand by inherent recoil have less risk of overexpansion and perforation while maintaining fixation against the tracheal wall.

Tracheal stenting is an ideal technique to palliate significant stenosis in patients who are not good surgical candidates. Stents are also useful during most airway augmentation procedures to support a free graft or a vascularized flap (Montgomery $\top$ tube, Eliachar stent, Montgomery laryngeal stent) and to preserve the lumen (Montgomery $\top$ tube). The reported ideal period of stenting for this purpose is not well defined, but most surgeons advocate stenting for 2 weeks to 10 months. As a general rule, 2 to 6 weeks of stenting is sufficient.

Although less invasive than transcervical approaches, stenting is associated with significant complications, including dislocation of the stent, obstruction with granulation tissue, and perforation caused by ischemic necrosis or erosion.[21,24] Nouraei and coauthors[25] noted a highly significant association between stent colonization with specific bacteria (*Staphylococcus aureus* and *Pseudomonas aeruginosa*) and the development of airway granulation. Stenosis of the proximal subglottic area is a relative contraindication to stenting. Because of its proximity to the vocal folds, stents in this area cause discomfort, coughing, and dysphonia.

Endoscopic Microsurgery

The success of endoscopic microsurgery depends on the cause, site, and extent of the stenosis (i.e., diameter, length); therefore, appropriate patient selection is essential. Endoscopic microsurgery for acquired laryngotracheal stenosis is likely to fail when used in patients with multiple stenotic sites, when the stenosis is associated with loss of cartilaginous support, when it extends for longer than 1 cm of the trachea or subglottis, when the lesion is circumferential, and when it is accompanied by the presence of bacterial infection.[26]

The use of topical mitomycin C, however, may expand the indications for this approach.[27–29] Mitomycin C is an alkylating agent that inhibits protein and DNA synthesis and is generally accepted as a safe and cost-effective adjunct to laryngotracheal surgery.[30] By subsequently inhibiting fibroblast proliferation, mitomycin C decreases the likelihood of restenosis. Eliashar and colleagues[28] investigated the use of topical mitomycin for the prevention of stenosis after acute injury to the larynx in dogs. They were able to reduce the incidence of stenosis from 85% to 27%. Rahber and coauthors[29] reported using topical mitomycin (at a concentration of 0.4 mg/mL for 4 minutes) as an adjunct to endoscopic laser surgery for laryngotracheal stenosis. Nine of 12 (75%) patients with subglottic or tracheal stenosis (or both) were decannulated via this technique. Similarly, in a retrospective review of topical mitomycin C, patients who were treated adjuvantly with mitomycin C after endoscopic microsurgery experienced a significantly longer symptom-free interval than did those who underwent endoscopic treatment alone (23.2 versus 4.9 months).[31]

Endoscopic microsurgery with partial excision is an ideal method for treating thin webs and less severe stenosis. Multiple wedge excision or radial incisions of the mucosal web augment the airway while still preserving enough epithelium to prevent restenosis (Fig. 70-3).[20] Topical mitomycin C may provide additional benefit.[27–31]

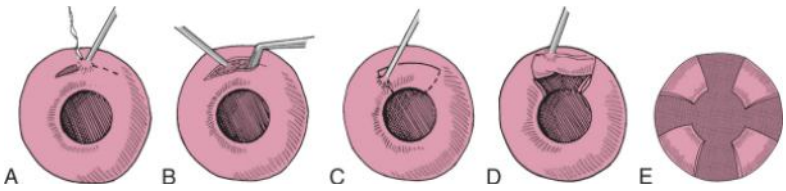

Figure 70-3 **A** to **E**, Radial wedge excision of a tracheal or subglottic web with the CO_2 laser. Wedge excision at each quadrant augments the airway and preserves enough epithelium to prevent restenosis.
(A to C, From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 509.)

Transcervical Procedures

Thick (>1 cm) and recurrent laryngotracheal stenoses are better corrected via an external approach to augment the lumen. The basic transcervical approaches include tracheotomy, $\top$ tube placement, resection of the stenotic segment with end-to-end anastomosis, and laryngotracheoplasty. One of the most popular techniques is augmentation with autologous free grafts. Cartilage from the septum, thyroid alae, or ribs may be harvested for use as a free graft. We prefer a rib graft because it is abundant, thicker, and easy to carve (Fig. 70-4). Other helpful augmentation techniques involve the use of myoperiosteal[32] or myocutaneous[33,34] flaps. Advocates of transcervical procedures believe that these approaches allow precise excision of scar tissue, facilitate primary healing by allowing the advancement of local flaps, and decrease the need for revision surgery.

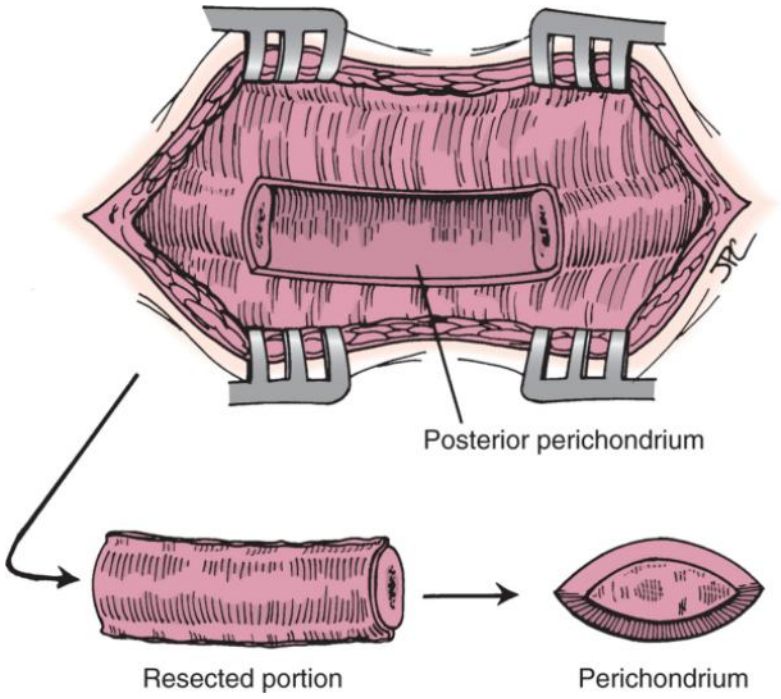

Figure 70-4 Harvesting of the sixth rib through a horizontal incision over the preferred rib. The inner perichondrium is preserved to provide sufficient cartilage and avoid injury to the pleura with subsequent pneumothorax. The cartilage is then carved in lock-and-key fashion.
(From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 470).

Acquired tracheal stenosis may be segmental or circumferential. The corrective procedure should strive to address the involved area while preserving adjacent normal tissue. Several principles are fundamental to the successful outcome of any surgery for laryngeal stenosis: (1) a secure airway during the perioperative period, (2) adequate exposure, (3) preservation of normal tissue, and (4) prevention of recurrence by promoting primary healing. Successful primary healing requires an adequate blood supply and tension-free anastomosis.

The best approach for the management of extensive tracheal stenosis is yet to be defined and must be individualized to each patient. The most challenging and controversial tracheal stenoses include those involving more than 50% of the length of the trachea; those associated with extrinsic or intrinsic malignant obstruction, laryngeal stenosis, or tracheomalacia; and recurrent tracheal stenosis after resection of four or more tracheal rings.

Laryngotracheal Reconstruction with Cartilage Autografts

Reconstruction for combined tracheal and subglottic stenosis can be achieved by anterior or posterior cricoid grafting, or by both. In general, anterior augmentation is usually recommended for moderate stenosis not associated with significant loss of cartilage and not associated with posterior glottic stenosis. Posterior augmentation is rarely used alone; rather, it is often combined with anterior grafting for severe stenosis (>75% of the lumen). However, in select pediatric patients, a posterior graft may be inserted endoscopically.

A horizontal incision following one of the skin creases is made in the inferior aspect of the neck. The incision is extended through subcutaneous tissue and the platysma. Subplatysmal flaps are elevated inferiorly to the clavicle and superiorly to the hyoid bone. The strap muscles are split in the midline to expose the laryngotracheal complex. A vertical laryngofissure is performed and extended into the upper two tracheal rings (Fig. 70-5). The cricothyroid membrane may be opened horizontally to facilitate lateral retraction of the cricoid chondrotomy segments and insertion of the graft. The mucosa is incised while preserving the anterior commissure, and the posterior mucosal surface of the larynx and trachea is exposed. It is important to suture the tendon of the anterior vocal fold (anterior commissure) to the anterior edge of the thyroidotomy. A posterior cricoid chondrotomy is performed, with preservation of the integrity of the cricoarytenoid joints and postcricoid mucosa. If the posterior glottis is scarred and stenotic, submucosal excision of the scar is performed. A free cartilage graft is carved to fit the posterior cricoid area (Fig. 70-6). Kirschner wires are passed into the graft to secure it in place. A similar technique is used for the anterior graft (Fig. 70-7). Alternatively, a rigid fixation plate may be used to fix the anterior graft in place, which is carved to fit in lock-and-key fashion, as described by Zalzal and Cotton.[35] The strap muscles and platysma are reapproximated with absorbable suture. A soft rubber drain (e.g., Penrose) is left in place. The skin is closed with staples and a compressive dressing is applied.

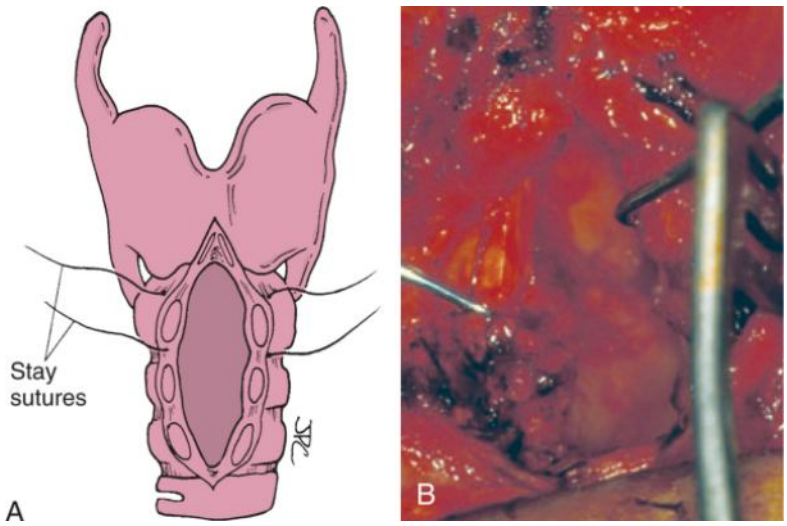

Figure 70-5 **A,** Anterior cricoid split. **B,** Vertical laryngeal and anterior tracheal incision.
(A, From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 470).

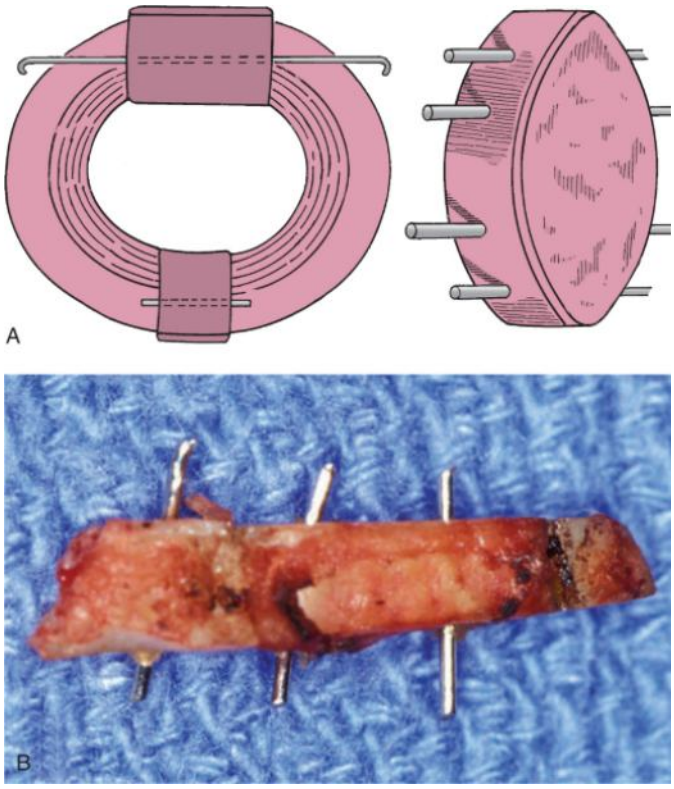

Figure 70-6 **A,** Placement of wires through the cartilage free graft as seen in an axial view with the anterior and posterior cartilage grafts in place. **B,** Kirschner wires (24 gauge) are inserted through the cartilage grafts to stabilize them. An adaptation plate may be used anteriorly.

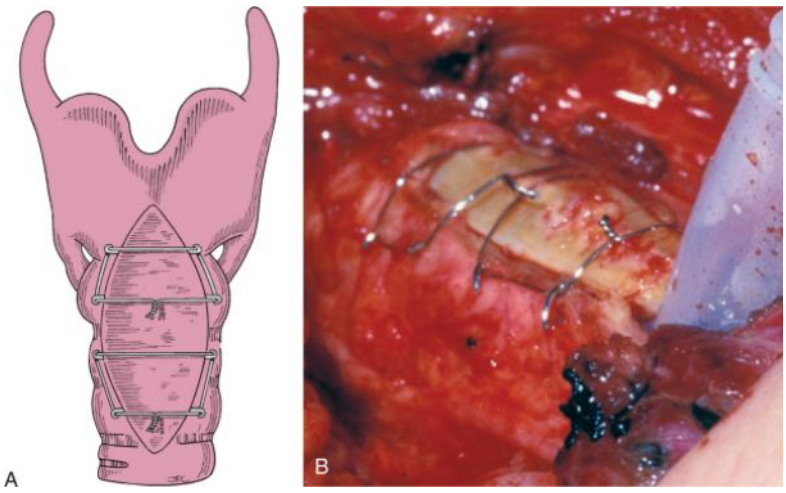

Figure 70-7 Illustration (**A**) and clinical photograph (**B**) of a cartilage graft in place demonstrating the wiring technique used to reconstruct an anterior tracheal defect.

Single-stage laryngotracheal reconstruction is preferred whenever possible and includes resection of the anterior cricoid cartilage and posterior subglottic mucosa (if involved by the scarring process).[36–40] The trachea is then cut into a design that fits into the defect; the anterior cricoid is therefore replaced by tracheal cartilage and the remaining posterior cricoid is relined by the membranous trachea.

Myoperiosteal Flap

A sternocleidomastoid myoperiosteal flap, as described by Friedman and Mayer,[32] is an excellent alternative technique for augmentation of the anterior cricoid ring and cervical trachea. The surgical approach and exposure are similar to those already described. The sternoclavicular origin of the left sternocleidomastoid muscle is exposed through the cervical invasion and mobilization of subplatysmal flaps. If necessary (e.g., in a patient with a long neck), a second horizontal incision is performed closer to the clavicle. The sternal head is transected, and the clavicular periosteum around the lavicular insertion is incised and elevated as a myoperiosteal flap (Fig. 70-8A to C). Enough clavicular periosteum is included in the flap to cover the tracheal defect. This flap is mobilized into the defect until tension-free closure is achieved. The flap is sutured to the anterior edges of the cricoid and trachea over a Montgomery $\top$ tube (see Fig. 70-8D and E). The wound is closed in multiple layers, a soft rubber drain is left in place, and a compressive dressing is applied. The periosteum eventually calcifies, thus maintaining mechanical stability of the lumen. A significant advantage of this technique is that harvesting of costal cartilage is not required. The rotation of the sternocleidomastoid muscle, however, produces a “bulge” deformity that may be unacceptable for some patients, although it does diminish significantly with time.

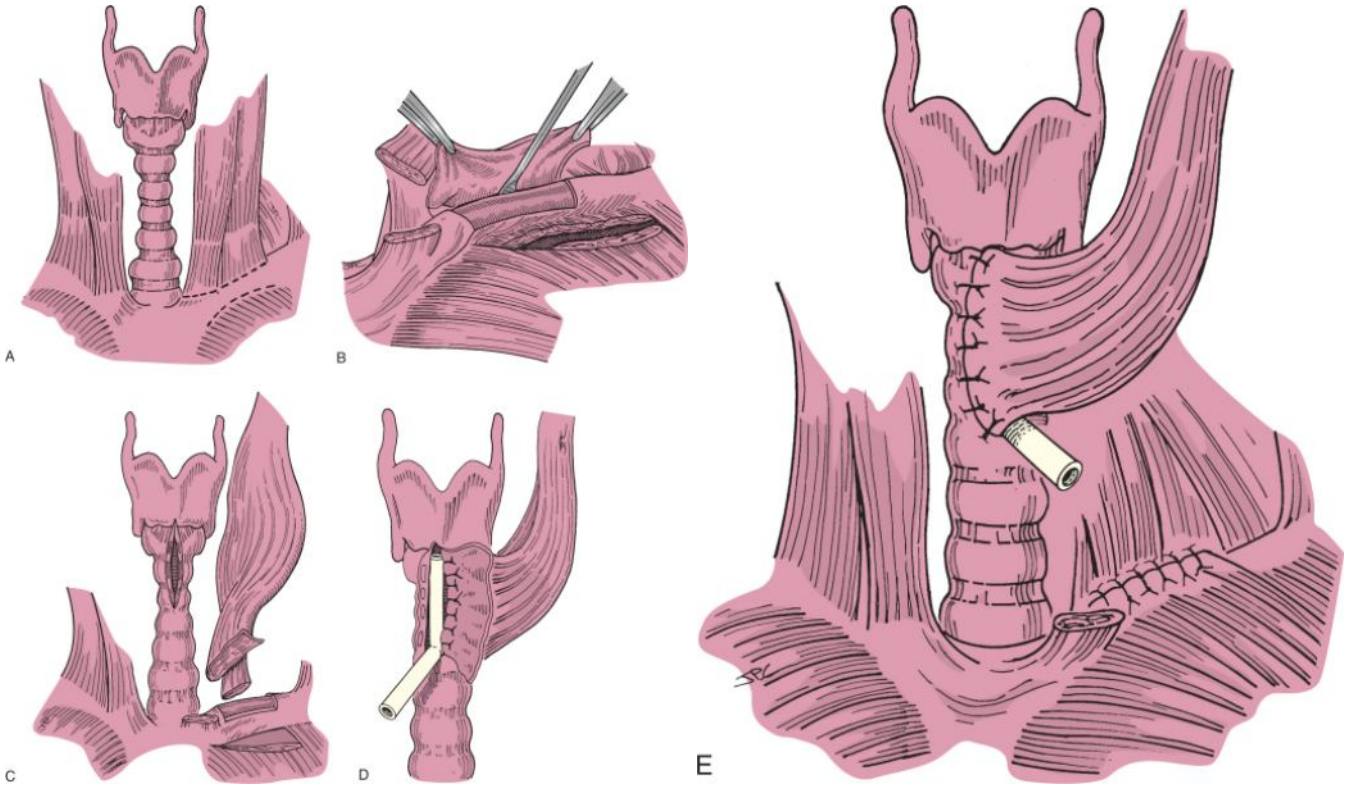

Figure 70-8 **A,** Surgical exposure of the sternoclavicular head of the sternocleidomastoid muscle and the area of the stenosis. **B,** The periosteum is elevated en bloc with the sternoclavicular head of the sternocleidomastoid muscle. **C,** The myoperiosteal flap is elevated. Branches of the thyrocervical trunk supplying the inferior aspect of the sternocleidomastoid muscles are usually sacrificed to enhance mobility of the flap. **D,** The myoperiosteal flap is sutured to the defect. A Montgomery T tube maintains the shape of the lumen and secures the airway. **E,** The myoperiosteal flap has been sutured to the defect.

Resection and End-to-End Anastomosis

Patients with more severe stenosis or significant loss of structural support, or both, may require resection of the stenotic segment. Exposure of the laryngotracheal complex is achieved as previously described (in the first paragraph of Laryngotracheal Reconstruction), and the trachea is dissected very close to its surface (Fig. 70-9). If necessary, a full-thickness, circumferential segment of the stenotic airway is resected while preserving as much normal trachea as possible (Fig. 70-10). Identification of the recurrent laryngeal nerves is not necessary except at their entrance to the larynx at the cricothyroid joints, provided that the dissection is kept on tracheal cartilage.

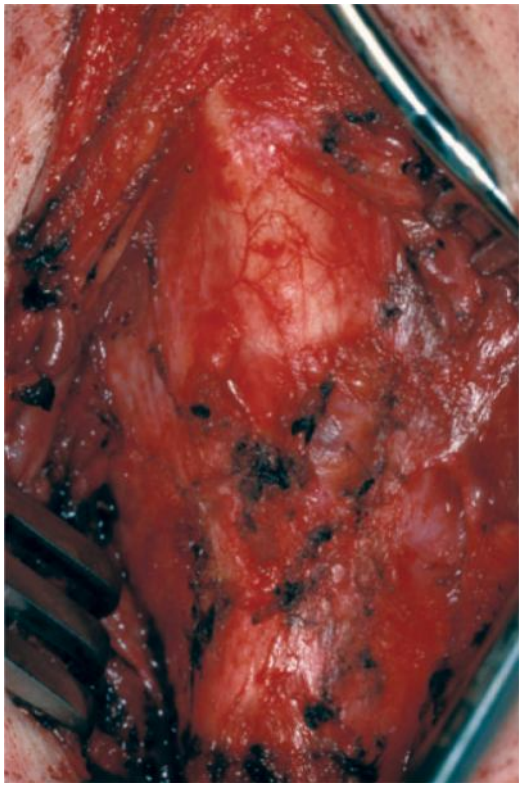

Figure 70-9 Exposure of tracheal stenosis.

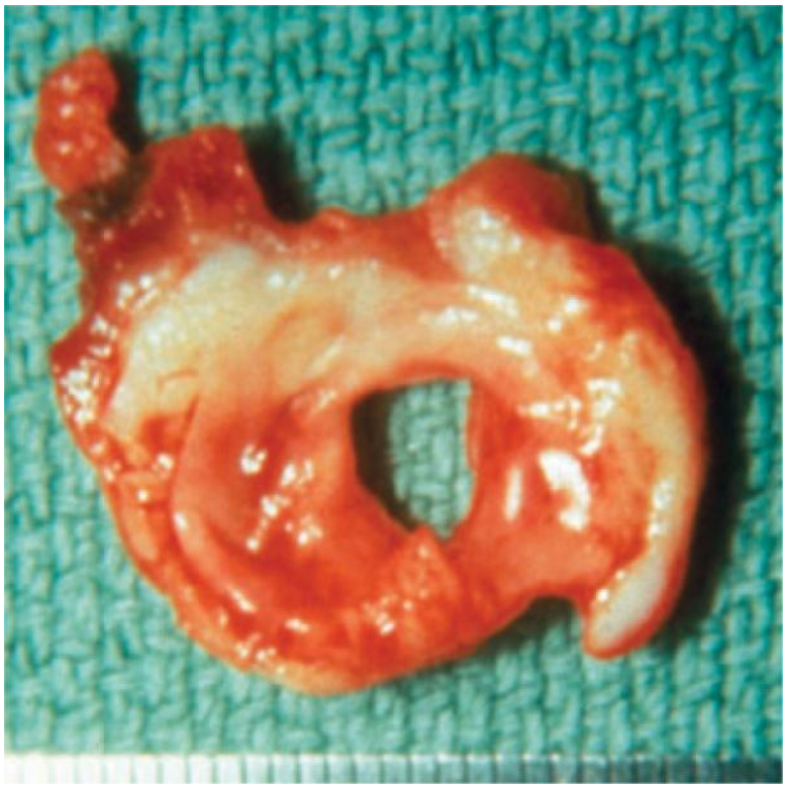

Figure 70-10 Circumferential tracheal resection (specimen).

It is critical that the blood supply to the trachea be preserved. Multiple branches from the inferior thyroid artery penetrate the trachea at its posterior lateral surface to provide a segmental blood supply consisting of a segment of six rings.[41,42] The thoracic trachea receives branches from the subclavian, right internal thoracic, and bronchial arteries.

The airway is maintained with an anode tube in the distal end of the trachea. It is useful to have sterile hoses to connect the anode tube to the anesthesia ventilation circuit to avoid having to exchange the connections from the endotracheal tube to the anode tube beneath the sterile drapes. Mobilization of the trachea is achieved by separating the membranous trachea from the esophagus posteriorly and by blunt dissection of the anterior and lateral surfaces of the trachea (sparing the blood supply). If needed, the suprahyoid musculature is transected from its insertion at the superior surface of the hyoid bone.[43] The anastomosis is then completed with chromic 3-0 stitches (taper needle) for the mucosa and submucosal Prolene 0 (or 28 wire) for the cartilage (Fig. 70-11). The anode tube is removed and the endotracheal tube is advanced into the trachea. A Prolene 1 stitch from the chin to the sternum is used to keep the head in a flexed position.

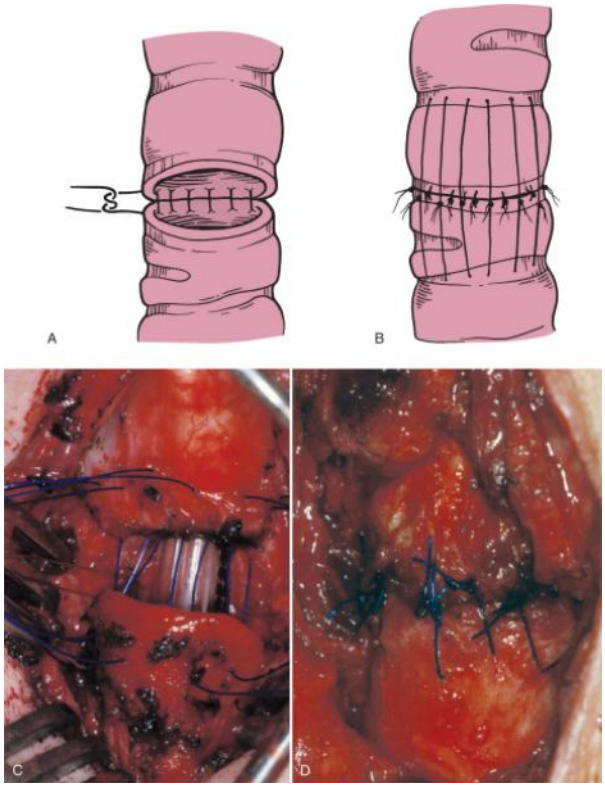

Figure 70-11 **A** and **B**, Sutures are placed through the mucosa so that the knots are outside the lumen. **C**, Sequential suturing of the membranous trachea so that the knots are outside the lumen. **D**, Completed end-to-end anastomosis.

Preferably, if a large segment is to be resected, a sliding tracheoplasty is performed.[44,45] This technique includes dividing the stenotic segment at the midpoint of its length, incising the two opposing segments vertically, one anteriorly and the other one posteriorly, and then sliding them together in a side-to-side anastomosis.[42] The length of the tracheal segment is shortened by one half, thereby doubling the circumference and quadrupling its luminal cross section.

If the lumen of the cricoid (subglottic) is involved, cricotracheal resection is performed.[46–50] The anterior and lateral cricoid cartilage and subglottic mucosa are resected. The posterior facet of the cricoid and the cricothyroid joints are spared. The posterior subglottic mucosa may be resected if scarred. The distal end of the trachea is then transected in a shape that will fit the cricoid defect. The posterior mucosa will be replaced by membranous trachea.

Despite refinements in surgical techniques, such as slide tracheoplasty and combined cervical and thoracic approaches to release the bronchi and mobilize the proximal part of the trachea, a significant number of patients have stenoses that are too extensive to be treated with traditional surgical approaches. In addition, combined transcervical-transmediastinal approaches are highly invasive and involve mobilization of the right hilum and pulmonary vessels, division of the pulmonary ligament, and division and reimplantation of the left main bronchus. Although effective, the morbidity associated with this approach is significant.

Homograft transplantation and autotransplantation may soon be feasible alternatives for these patients.[51–55] The success of any grafting or transplantation depends on adequate vascularization, tension-free anastomosis, and lack of an immune reaction that would destroy the cartilaginous framework. Hashimoto and colleagues[52] assessed the feasibility of achieving successful transplantation via immunosuppression. Kunachak and coworkers[54] were able to decannulate three of four patients with the use of cryopreserved, irradiated tracheal homograft. All these patients had failed other conventional attempts at tracheal reconstruction. The use of autografting with and without revascularization with flaps has also been suggested.[55]

POSTOPERATIVE MANAGEMENT

Patients are transferred to an intermediate or intensive care unit for continuous monitoring and frequent tracheotomy care. Whenever an end-to-end anastomosis is performed, tension is avoided in the immediate postoperative period by maintaining the head in a flexed position. A Prolene 1 stitch from the mentum to the sternum serves to secure this position. Patients are kept with the head of the bed elevated at 30 degrees to diminish the possibility of gastric reflux and to facilitate ventilation. Humidified air is delivered by face or tracheotomy mask, accordingly. This is critical to avoid crusting and facilitate mobilization of tracheobronchial secretions. Delivery of oxygen via a ┬ tube attachment to the tracheostomy tube is not recommended because it exerts traction on the tracheotomy tube, thereby eliciting pain and cough. Furthermore, this traction may break the peristomal sutures and lead to gross contamination of the wound with tracheal secretions.

Patients are not fed during the first 24 hours after surgery to diminish the possibility of nausea and vomiting, which may stress the repair. A nasogastric tube for suctioning the stomach contents during the initial postoperative period is recommended for the same purpose.

The tracheotomy tube may be downsized or changed to a cuffless tube 72 hours after the procedure. This allows the formation of a tract that greatly facilitates insertion of the second tube. In cases in which an external approach was used, such as a laryngofissure, it is prudent to keep a cuffed tracheotomy tube in place for 5 to 7 days to prevent massive subcutaneous emphysema and contamination of the cervical wounds when air and secretions are insufflated through the endolaryngeal wound.

The patient should be able to breathe and protect the airway from aspiration before the tracheotomy tube is removed. Clinical signs such as an ability to tolerate a plugged tracheotomy tube and the absence of bronchorrhea, choking, or other signs of aspiration suggest that the patient is ready to be decannulated. Examination with a flexible laryngoscope is an invaluable adjunct to ascertain adequacy of the airway and the pharyngeal phase of swallowing, as well as to monitor the healing process.

Patients who need a long-term tracheotomy tube or ┬ tube stent should be trained in the care of these artificial airways. The caregivers or companions of these patients must be aware of the possible complications and be proficient in emergency maneuvers such as removal and reinsertion of the tracheotomy tube. In the case of ┬ tube stents, caregivers or companions should be instructed on removal of the stent and insertion of a tracheotomy tube.

COMPLICATIONS

Early complications consist of prolonged intubation secondary to glottic edema or edema in the area of the anastomosis, as well as superficial infection. Suture granulomas in the tracheal incision occur occasionally, and removal of these granulomas by repeated bronchoscopy may be necessary. Grillo and associates[47] described a series of patients who had difficulty with deglutition or aspiration postoperatively. All eight patients had undergone extensive resection, including suprahyoid laryngeal release in four of them. One patient required a gastrostomy tube for treatment, and some patients also had diminished vocal quality or projection after surgery.

Granulation tissue at the suture line was the most common problem early in Grillo and colleagues' series and necessitated repeat bronchoscopy and, occasionally, injection of triamcinolone through an endoscope into the base of the removed granulation tissue.[47] Since the introduction of absorbable Vicryl suture, the problem of anastomotic granulation has markedly decreased or is absent.

PEARLS

- Tracheal stenosis may originate from a wide variety of etiologic factors; however, the pathogenesis typically involves a mucosal or cartilaginous injury (or both) leading to scarring, loss of structural support, and an inflammatory reaction.
- Multiple factors play a role in the development of tracheal stenosis after endotracheal intubation, but cuff pressure appears to be the most significant.
- Intraoperative control of the airway is paramount in any surgery for laryngotracheal stenosis.
- Endoscopic microsurgical techniques, with or without adjunctive procedures such as intralesional steroid injection or application of mitomycin C, are ideally suited for management of thin webs or other less severe stenoses with good cartilage support.
- Poor candidates for major reconstructive surgery may best be managed by repeated dilatation or stenting.

PITFALLS

- Failure to control gastroesophageal reflux in the perioperative period may contribute to recurrent or persistent laryngotracheal stenosis.
- In the office setting, passing a flexible scope through a significant tracheal stenosis may lead to airway compromise and a clinically unstable situation.
- Severe or recurrent stenoses are often not amenable to conservative endoscopic therapy and usually require tracheal resection with cartilage graft reconstruction or end-to-end anastomosis for definitive management.
- Although tracheal stents provide a less invasive option for patients with associated malignancy or comorbid medical conditions, stenting can result in significant complications such as dislocation or migration, obstruction with granulation tissue, and perforation.
- Compromising the blood supply to the trachea during resection and reconstruction may lead to postoperative complications such as wound dehiscence and restenosis.