Chapter 45 – Acquired Laryngeal Stenosis

Ryan J. Soose,
Ricardo L. Carrau

The basic functions of the larynx include being the conduit for air, protecting the airway from aspiration, phonating, coughing, fixing the chest for straining activities, and maintaining positive end-expiratory pressure. All these functions are impaired in patients with stenosis.[1–4]

Acquired laryngeal stenosis is a rare condition. Stell and colleagues estimated that the average otolaryngologist can expect to see five cases during an entire career.[4] Laryngeal stenosis may arise from a variety of causes, and the degree of laryngeal dysfunction ranges widely. The diversity of treatment methods reported in the literature is matched only by the imagination of the surgeons dealing with the problem.

ANATOMIC CONSIDERATIONS

The larynx is protected by the mandible, the sternum, and the flexion mechanism of the neck. Nevertheless, it can be injured by external or iatrogenic trauma. Systemic diseases, infections, and neoplasms may also cause stenosis.

Injury to the laryngeal soft tissue or its cartilaginous framework can lead to scarring and loss of support, with subsequent collapse of the airway and stenosis. The laryngeal cartilaginous framework depends on the perichondrium for blood supply. Cartilage deprived of its blood supply necroses rapidly and acts as a foreign body that induces an inflammatory reaction and causes further tissue destruction and scarring. After injury, the soft tissue planes of the larynx are disrupted and filled with blood, which may develop into an organized hematoma and further fibrosis.

The site of injury also influences the development of stenosis. Different areas of the larynx have intrinsic characteristics that protect or predispose to various injuries. The supraglottis has more soft tissue and more redundant mucosa and is less dependent on external support than the glottis or subglottis is. Supraglottic structures such as the hyoid and epiglottis can be sacrificed without significant loss of laryngeal function. Injuries to the supraglottis are therefore associated with a better prognosis.

The glottis represents the narrowest area in the adult airway. The soft tissue of the glottis depends on cartilaginous support, cricoarytenoid joint mobility, and perfect neuromuscular coordination for normal function. The recurrent laryngeal nerve has preferential innervation of the adductor muscles, which predisposes the glottis to abductor paralysis with injury.

The subglottic area is supported by the cricoid ring, the only circular cartilage in the laryngotracheal complex and the narrowest part of the airway in neonates. The subglottis is lined with respiratory epithelium over a submucosa composed of loose areolar tissue. Respiratory epithelium is not well suited to tolerate trauma and is easily disrupted, thereby leading to healing by secondary intention and scarring. These factors make the subglottis more susceptible to stenosis than any other region of the larynx.

ETIOLOGY

External Trauma

Increased civilian violence and motor vehicle accidents have led to an increase in the incidence of post-traumatic laryngeal stenosis. Even when adequate and immediate repair is accomplished, severe disruption of supporting structures or laryngotracheal separation is usually accompanied by some degree of airway narrowing.[5–7] The incidence of laryngeal stenosis after external trauma varies from 0% to 59%.

Intubation

The incidence of laryngeal stenosis after prolonged or repeated intubation has been estimated to range from 3% to 8% in both adults and children.[8–11] Figures as high as 44% have been cited for low-birthweight neonates and those with respiratory distress syndrome.[8–12] Earlier endoscopy and tracheotomy in low-birthweight infants and other high-risk groups may reduce the frequency of intubation-related laryngotracheal stenosis in these patients.[12]

Causes of laryngeal stenosis after intubation are multifactorial. Mechanisms of laryngeal injury most commonly associated with laryngotracheal intubation include time of intubation, size of the tube, pressure and rubbing of the shaft against the larynx, repeated intubation, foreign body reaction to the tube, release of toxic substances used for sterilization, use of a stylet, route of intubation, nursing care, and anatomic differences between the genders.

Animal and clinical studies have correlated different intubation methods with clinical and histologic injury patterns. Nordin and Linholm,[13] in a rabbit model, correlated the degree of damage with time of intubation and cuff characteristics. They concluded that the pressure of the cuff over the tracheal surface is more important than the length of intubation. Because the microcirculation of the laryngeal mucosa stops at a pressure of 30 mm Hg, low-volume, high-pressure cuffs are more likely to cause ischemic injury than high-volume, low-pressure cuffs are.

Whited,[14] in a dog model, studied how the biomechanics of endotracheal tubes produces ulceration of the posterior glottis and circumferential injury to the subglottis and trachea. He demonstrated that the inflammatory reaction progresses even after the tube is removed. Whited[15] confirmed the findings of his animal study in a clinical prospective study in which the degree of injury was correlated with patterns and length of intubation. He found that patients intubated for 2 to 5 days had a 0% to 2% incidence of chronic stenosis, those intubated for 5 to 10 days had a 4% to 5% incidence, and those with an indwelling tube 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.

Bryce[16] also correlated the time of intubation with laryngeal injuries. Lesions caused by repeated intubation were the most severe. This study 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,[9] whereas adults are more prone to posterior commissure lesions.[8,11] Nevertheless, combined stenosis accounts for about one third of all cases of laryngeal stenosis at any age.

Tracheotomy

A high tracheotomy may be associated with glottic and subglottic injury. The type of incision and biomechanical factors related to the tube contribute to the development of stenosis.[17] Ideally, a tracheotomy should be performed through the third or fourth tracheal ring. A high tracheotomy through the first tracheal ring or the cricoid cartilage may lead to cricoid chondronecrosis with resultant fibrosis and stenosis.

Similarly, cricothyroidotomy has been associated with a higher incidence of laryngeal stenosis than tracheotomy has. The cricothyroid membrane ranges from 8 to 13 mm (average of 9 mm) in adults.[18] Damage to the cricoid as a result of the introduction of microorganisms or direct trauma to the cartilage may lead to chondronecrosis. Tracheotomy tubes are poorly suited to intubate the subglottic larynx because of the lack of overlying soft tissue. In addition, the outer diameter of a no. 6 Shiley tracheotomy tube is 10 mm, which is larger than the height of the cricothyroid membrane in a significant proportion of the population.

Endoscopy

The effects of endoscopic instruments on the laryngeal airway reflect the care and skill of the operator. Rough handling of tissue, excessive biopsy of tissue, inadvertent or inaccurate laser ablation, and oversized instruments all promote tissue fibrosis and stenosis.

Caustic Burns

The sphincteric action of the supraglottis often impedes contact of an ingested caustic agent with the glottis. Consequently, severe caustic burns of the supraglottis usually occur without any involvement of the glottis. The pharyngeal walls, however, are commonly injured as the chemical passes into the cervical esophagus. Caustic burns are characterized by extensive destruction of mucosa, submucosa, and muscles. The subsequent wound contracture and fibrosis may result in dysfunction.

Nasogastric Intubation

Nasogastric tubes are an often overlooked source of trauma. Nasogastric intubation produces inflammation secondary to a foreign body reaction to the tube, swallowing impairment with pooling of secretions, pressure necrosis, and gastropharyngeal reflux. All these factors play a role in the development of postcricoid ulceration with resultant perichondritis. Healing leads to fibrosis and contracture. The trauma associated with the nasogastric tube may be synergistic with the trauma induced by an endotracheal tube.

Infectious 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.[19] Laryngeal syphilis and tuberculosis (Fig. 45-1A), as well as diphtheria, though seldom encountered today in the United States, were common causes of stenosis in the past. In addition, Wegener's granulomatosis (Fig. 45-1B and C) and sarcoidosis (Fig. 45-1D) may affect the larynx. Subglottic stenosis occurs in 10% to 20% of patients with Wegener's granulomatosis, and the mainstay of treatment remains nonsurgical (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 medical treatment failures and is performed only during disease remission.[20,21]

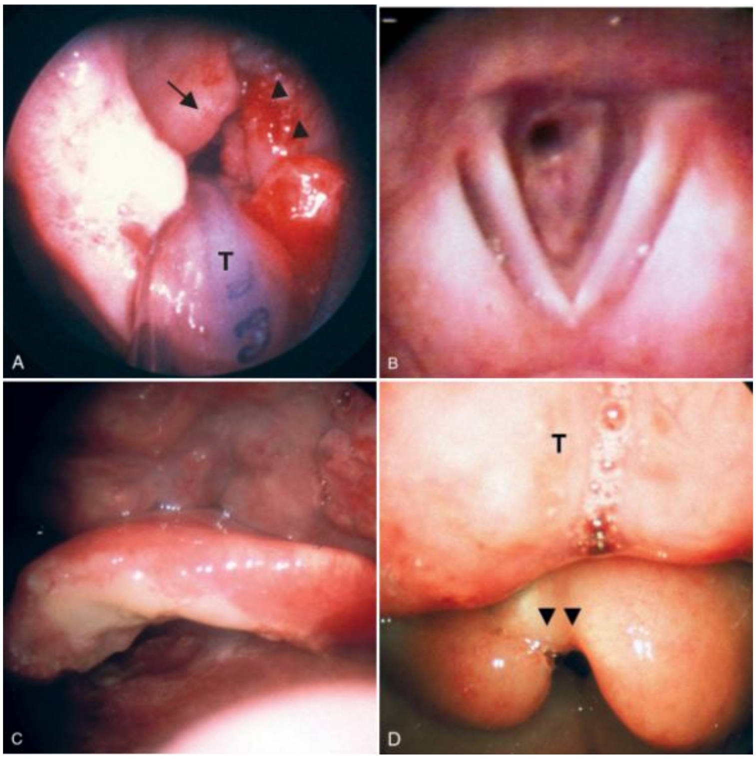

Figure 45-1 Laryngeal involvement. **A**, Tuberculosis: ulceration and granulation tissue *(arrowheads)* in the right false vocal cord; edema *(arrow)* of the left false vocal cord. T, endotracheal tube placed over the posterior glottis. **B**, Wegener's granulomatosis: subglottic stenosis. **C**, Wegener's granulomatosis: epiglottic ulceration. **D**, Sarcoidosis: epiglottic scarring *(arrowheads)*. T, tongue.

Autoimmune Diseases

Autoimmune diseases such as relapsing polychondritis (Fig. 45-2) may destroy the cartilaginous framework or affect the laryngeal joints and lead to collapse of the airway or fixation of the cricoarytenoid joint. Cricoarytenoid joint fixation may be the initial manifestation of rheumatoid arthritis.

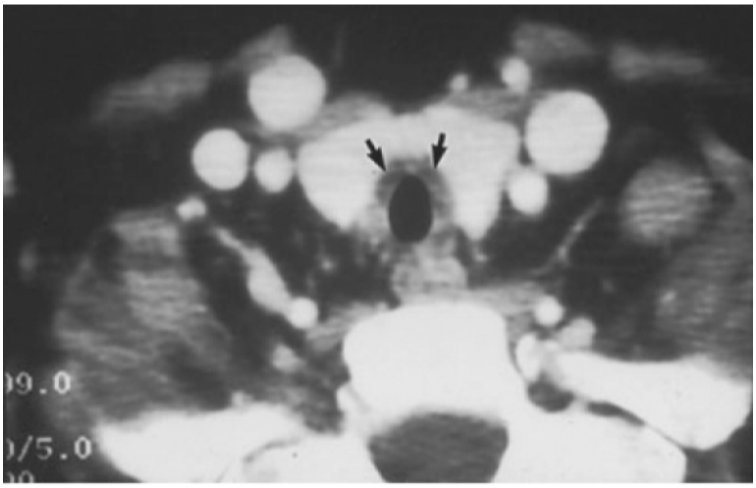

Figure 45-2 Computed tomography scan of a patient with active relapsing polychondritis demonstrating edema of the perichondrium of the cricoid cartilage and resorption of the cartilage *(arrows)*.

Gastropharyngeal Reflux

Repeated exposure to pepsin and acid from gastric reflux produces mucosal and submucosal injury and thereby leads to more scarring (Fig. 45-3).[22] Prophylaxis with antireflux medications is recommended after any laryngeal injury. Patients should be carefully monitored for gastroesophageal reflux, and those with recalcitrant stenosis must be assumed to be suffering from gastroesophageal reflux and be treated accordingly.

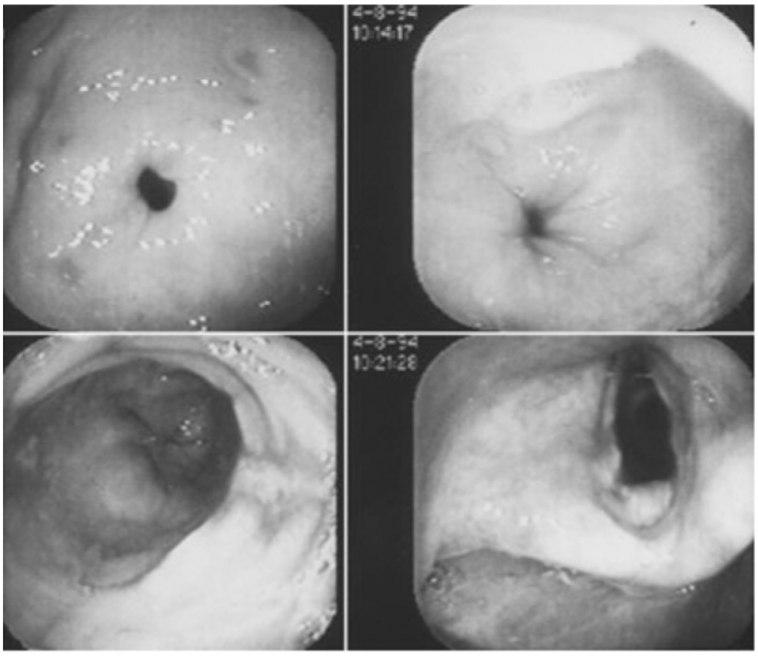

Figure 45-3 **Lower right**, vocal cord edema, pachyderma laryngis, and granuloma at the vocal processes. The other photographs show punctate and erosive esophagitis at different levels of the esophagus.

PATIENT EVALUATION

Clinical Assessment

Patients with laryngeal stenosis may complain of shortness of breath, dyspnea on exertion, stridor, hoarseness, difficulty swallowing, aspiration, difficulty clearing secretions, or any combination of these symptoms and signs. Although airway symptoms have traditionally been the primary focus, recent studies have shown a significant subjective and objective impairment in the vocal quality of patients with laryngeal stenosis.[23,24] Children often have a history of recurrent croup or cardiopulmonary problems.

In the office setting, flexible fiberoptic laryngoscopy is essential for evaluating the site and degree of stenosis, as well as vocal fold mobility. In a retrospective review of pediatric cricotracheal resection, multivariate analysis revealed that unilateral or bilateral vocal fold immobility was the only significant risk factor for failure of decannulation after airway reconstruction.[25] Video laryngoscopy and still photographs provide objective documentation that can be discussed with the patient and reviewed by other laryngologists. Electromyography helps differentiate neuromuscular deficits from cricoarytenoid joint fixation or subluxation.

Rigid direct laryngoscopic examination aided by the use of rod lens endoscopes, with the patient under general anesthesia, complements the office examination. Rigid direct laryngoscopy allows evaluation of the passive motion of the arytenoids and circumferential examination of the subglottis and provides an idea of the firmness of the scar tissue. Endoscopic methods of quantifying the extent and severity of the stenosis, as well as monitoring the success of treatment, have been reported.[26] When tracheal or laryngeal malacia is suspected, fiberoptic or rigid laryngobronchoscopy should be performed with the patient breathing spontaneously.

Noninvasive methods of improving the diagnosis and monitoring patients with laryngeal stenosis are available and have a promising future; however, their practical role in the clinical setting remains unclear. Nouraei and colleagues developed and tested a model based on flow-volume loops that can be used to quantify the mechanical extent and clinical impact of laryngotracheal stenosis.[27]

Imaging

Computed tomography (CT) is considered the standard imaging technique to corroborate the integrity of the cartilaginous framework and evaluate the cricoarytenoid joint (Fig. 45-4). Carretta and coworkers[28] compared the preoperative endoscopic and CT evaluations with the intraoperative findings in 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.[28]

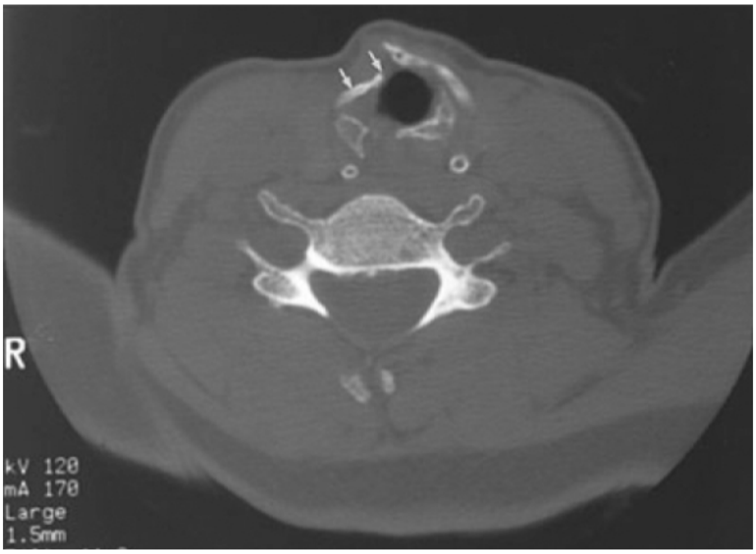

Figure 45-4 Computed tomography scan, axial view, demonstrating fractures involving the thyroid and cricoid cartilage *(arrows)*.

Other pertinent imaging modalities include magnetic resonance imaging (MRI), ultrasound, and fluoroscopy. MRI is useful in the evaluation of extensive laryngotracheal stenosis and does not involve any radiation exposure. It allows evaluation in the sagittal and coronal planes, which may be useful in treatment planning. A major limitation of MRI, however, is that the patient must lie quietly for a long time, which is not tolerated by children or by adults with significant stenosis secondary to orthopnea. Ultrasound may provide a convenient, well-tolerated, noninvasive method of assessing subglottic airway diameter.[29] Fluoroscopy is most helpful in evaluating areas of tracheomalacia that may collapse on inspiration but look normal during rigid direct endoscopy performed under general anesthesia. In small children, soft tissue radiographs may be sufficient to localize and grade the stenosis.

GENERAL MANAGEMENT

Treatment of laryngeal stenosis has evolved, although not in a linear fashion, from the "wait-and-see" philosophy to dilatation and eventually to endoscopic procedures with microsurgery. These surgical approaches have been combined with the use of antibiotics, stents, corticosteroids, and lumen augmentation procedures with or without grafts. Unfortunately, none of these techniques offers a 100% decannulation rate. Most clinical studies addressing the different therapeutic options are limited by their retrospective, nonrandomized nature and lack of standard definitions. Furthermore, reports on the use of different surgical methods and ancillary procedures, such as stenting and steroids, and similar techniques by well-recognized laryngologists have led to opposite findings and conclusions.

"Wait-and-See" Approach

This approach has been applied to children with congenital stenosis in the hope that the patient will outgrow the defect. When dealing with acquired laryngeal stenosis, the continuous process of scar maturation and contraction makes this outcome very unlikely. Therefore, the wait-and-see philosophy is rarely justified for patients with acquired laryngeal stenosis.

Dilatation

Dilatation is most successful when used for select cases of thin, congenital webs. Acquired stenosis usually implies a more severe stenosis that resists dilatation and is characterized by hyalinization of the connective tissue and collagen cross-linking that translates into an incompressible, rigid scar.[3]

The success rate of dilatation improves when the technique is used for soft or immature scars of minimal thickness and when it is used as an adjunct to other techniques (e.g., radial incisions). It may offer palliation to patients in poor general medical condition.[30] A significant disadvantage of the technique is the need to repeat the procedure a number of times on each patient. Overall, approximately three quarters of patients treated by dilatation as primary therapy will have recurrence of the stenosis and require a subsequent intervention.[31,32]

Endoscopic Microsurgery

The outcome after endoscopic microsurgery depends on the cause, site, and extent of the stenosis; therefore, appropriate patient selection is essential. Endoscopic microsurgery for acquired laryngeal 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 is wider than 1 cm, when the lesion is circumferential, and when accompanied by the presence of bacterial infection.[30]

Endoscopic Laser Microsurgery

Laser surgery offers the unique advantages of hemostasis and a visual field not obscured by instruments. Whether the laser is less traumatic than microsurgical instruments is somewhat controversial. Experimental data suggest that wounds produced by a laser beam show early re-epithelialization with slow fibroblast proliferation and collagen formation. However, as a general rule, microsurgical instruments better preserve normal tissue. Large defects heal by secondary intention (i.e., increased scarring) irrespective of the method of incision.[1–3] The main disadvantages of the CO_2 laser are cost, risk of fire, and corneal burns.

Many patients with posterior glottic stenosis may be decannulated with preservation of a good to fair voice after laser excision of the scar via a trapdoor flap[33] or arytenoidectomy, or both.[34]

External Procedures

The basic transcervical approaches include lateral pharyngotomy, resection of the stenotic segment with end-to-end anastomosis, and median thyrotomy. Advocates of transcervical procedures believe that these approaches allow precise excision of scar tissue, facilitate primary closure by allowing the advancement of mucosal flaps, and therefore decrease the need for revision surgery.[35]

ANCILLARY TECHNIQUES

Stenting

The use of a stent or "lumen keeper" is another subject of controversy. The intent of stenting is to maintain the lumen while allowing the dynamics of wound healing to occur about a relatively inert object that resists the contraction process. Surgeons opposed to stenting suggest that even the most inert material can lead to a foreign body reaction with exacerbation of the inflammatory response, further destruction of tissue, and slow re-epithelialization.

Stents have been molded with rigid and soft materials. Rigid stents (i.e., lumen keepers) are not recommended because they produce trauma that is similar to that of endotracheal tubes. The most popular stents are soft stents such as finger cots filled with sponge or nasal packing material, rolled Silastic sheets, and tubular or solid prefabricated Teflon or Silastic stents (Fig. 45-5).

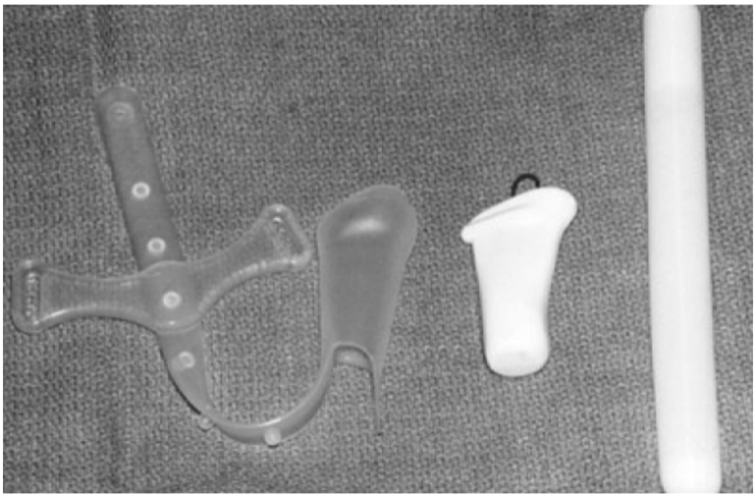

Figure 45-5 Prefabricated stents. Left to right are shown the Eliachar, Montgomery, and Aboulker stents.
*(**Left** and **center**, From Boston Medical Products, Westborough, MA.)*

Finger cots are easily designed and customized to the needs of the case and are inexpensive. However, they produce a significant foreign body reaction and can become a source of infection if contaminated by saliva. Silastic stents can be made with softened endotracheal tubes or rolled Silastic sheets. Rolled silicone sheets induce exuberant granulation tissue. Prefabricated silicone and Teflon models are available in different sizes and lengths and allow modifications; these are the preferred materials (Fig. 45-6). Stents are most useful in the postoperative setting as an adjunct to most airway augmentation procedures to support a free graft or a vascularized flap and to preserve the lumen. The reported ideal period of stenting ranges from 2 weeks to 10 months.[36,37] As a general rule, 2 to 4 weeks of stenting is sufficient. Stents can also be used as primary treatment of complex cases with stenoses at multiple sites or as a salvage effort in patients who have failed multiple attempts at airway reconstruction.[38] Nevertheless, stents can be problematic and require heightened attention to their potentially life-threatening complications.

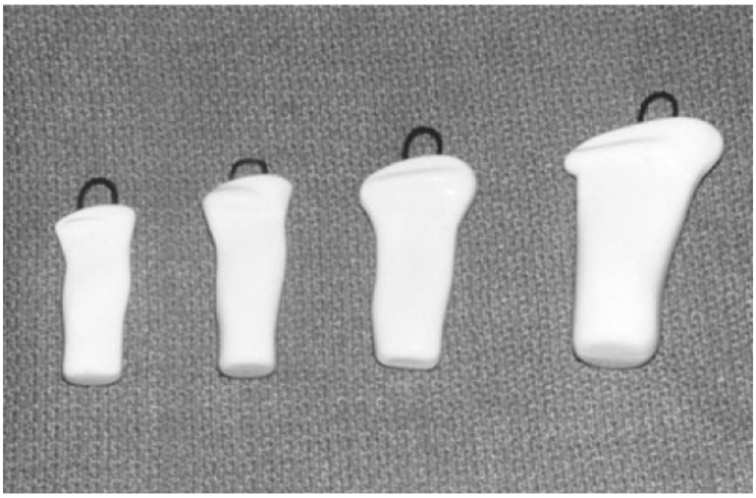

Figure 45-6 Different sizes of Montgomery laryngeal stents. Left to right are shown child, small adult, medium adult, and large adult stents.

Corticosteroids

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. Their clinical benefits for laryngeal stenosis are unproved, but for laryngeal stenosis, intralesional injections may be of benefit to soften scar bands and synechiae.

Mitomycin C

Mitomycin C is generally accepted as a safe and cost-effective adjunct to laryngotracheal surgery.[39] An alkylating agent that inhibits protein and DNA synthesis, it acts by impeding fibroblast proliferation, thus decreasing the probability of restenosis.[40] Eliashar and associates[41] investigated the use of topical mitomycin C 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%. Rahbar and coauthors[42] reported using topical mitomycin C (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 with this technique. Similarly, in a retrospective review of topical mitomycin C, patients who were adjuvantly treated 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).[43]

Antibiotics

Laryngeal surgery is classified as a clean-contaminated procedure, for which perioperative prophylactic antibiotics are recommended. A prolonged therapeutic course of antibiotics may be indicated in special circumstances (e.g., active chondritis). Nouraei and colleagues noted a highly significant association between stent colonization with specific bacteria (*Staphylococcus aureus* and *Pseudomonas aeruginosa*) and the development of airway granulation.[44] The theoretical value of a prolonged course of antibiotics is to control the infection, thus stopping a vicious cycle of chondritis, necrosis, granulation tissue formation, and scar deposition.

PREOPERATIVE PLANNING

Establishing and securing the airway are the keystones to all procedures for correction of laryngeal stenosis. The airway may be secured with an endotracheal tube or a tracheotomy.

A tracheotomy performed with the patient under local anesthesia is recommended for patients with significant airway compromise (e.g., stridor) and those who require a transcervical approach.

Patients who have a thin web that is amenable to endoscopic procedures and will require minimal surgical manipulation and select patients with supraglottic and subglottic mucosal stenosis may be intubated. Gentle handling of tissue during surgery is fundamental to prevent postoperative edema and compromise of the airway. The use of steroids in the perioperative period, although their benefit has not been scientifically proved, may help minimize the edema.

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

SURGICAL TECHNIQUE

Three basic principles are fundamental to the successful outcome of any surgery for laryngeal stenosis: adequate exposure, preservation of normal tissue, and prevention of recurrence by promoting primary healing.

Supraglottic Stenosis

Supraglottic stenosis is amenable to laser excision or transcervical supraglottic laryngectomy. As opposed to an oncologic supraglottic laryngectomy, this procedure preserves the innervation of the superior laryngeal nerves, the hyoid bone, and the soft tissues adjacent to the scarred area.[45]

A horizontal incision is incorporated into a horizontal skin crease over the thyroid cartilage. Subplatysmal flaps are elevated superiorly to expose the insertion of the suprahyoid musculature and inferiorly to the level of the cricoid. The infrahyoid strap muscles are transected at their insertion to expose the portion of the hyoid bone medial to the lesser cornua (Fig. 45-7). The strap muscles are dissected from the thyroid cartilage. The pharynx is entered as described for transhyoid pharyngotomy (see Chapter 29) (Fig. 45-8). This allows direct visualization of the stenosis. Thyrotomy cuts are performed with a no. 10 blade or an oscillating saw if the cartilage is calcified. The superior cornua of the thyroid cartilage, as well as the superior laryngeal neurovascular bundles, are spared. The soft tissue incisions include the stenotic area after the thyrotomy cuts are made (Fig. 45-9). The defect is repaired by suturing the base of tongue to the perichondrium of the thyroid ala. If the epiglottis is not sacrificed, it is incorporated into the closure. It is important to tack the epiglottis anteriorly to the remaining thyroid cartilage or the epiglottis will fold down and obstruct the view of the glottis posteriorly in the postoperative period. The strap muscles are reapproximated to the hyoid bone and to each other at the midline. The wound is repaired with a multilayer technique. Suction drains are left in place.

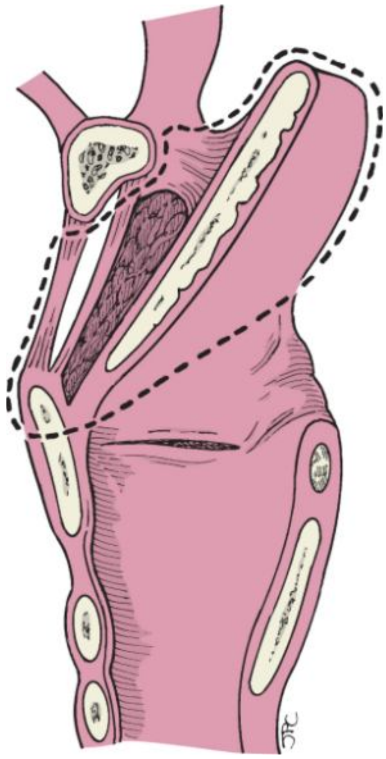

Figure 45-7 Sagittal plane. The *dashed line* bounds the area to be resected during partial supraglottic laryngectomy.

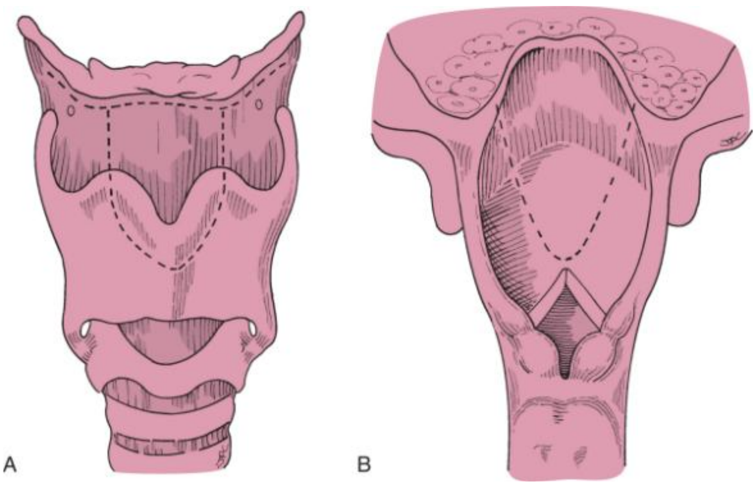

Figure 45-8 Coronal plane. The *dashed lines* indicate the level of incisions through the thyrohyoid membrane and the thyroid chondrotomies (**A**) and the endolaryngeal incisions (**B**).

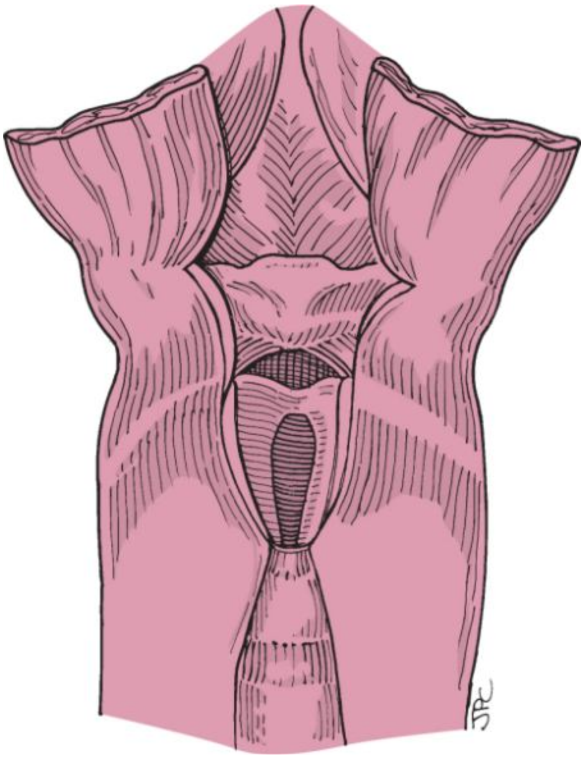

Figure 45-9 Coronal plane. In a transcervical view after removal of the median supraglottis, the vocal cords can be seen through the defect. The hyoid bone has been preserved.

In select cases, such as patients with poor general status, some temporary palliation may be achieved with a submucosal injection of corticosteroids and dilatation.

Glottic Stenosis

Stenosis of the glottic area should be further classified as anterior, posterior, or combined lesions. This simple classification is important because the cause, treatment, and prognosis are very different for these types of stenosis.

Anterior Glottic Stenosis

Anterior glottic stenosis usually develops after disruption of the anterior commissure by external trauma (e.g., laryngeal fracture), endoscopic surgery (e.g., vocal cord stripping), or oncologic surgery (e.g., partial vertical laryngectomy). Anterior glottic stenosis causes foreshortening of the glottis and tethers the abduction of the true vocal cords (Fig. 45-10A and B).

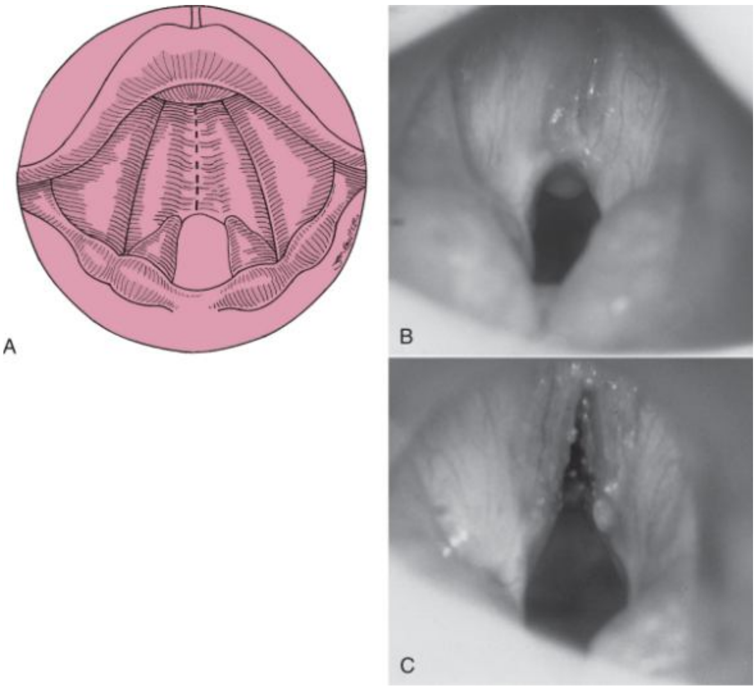

Figure 45-10 **A**, Anterior glottic web involving the vocal folds. The *dashed line* indicates the ideal level for lysis of the web to re-create the free edge of both true vocal cords. **B**, Intraoperative view of an anterior glottic web. **C**, Intraoperative view after division of the web with a CO_2 laser.

The method of resection, whether to use a laser or "cold" microsurgical instruments or to approach the lesion endoscopically or transcervically, is less important than good surgical technique that will widen the airway and promote primary healing. Magnification of the surgical field with a microscope or loupes optimizes preservation of normal tissue, and adequate instrumentation is important to minimize tissue trauma.

Invariably, correction of anterior glottic stenosis will result in two opposing surfaces with denuded epithelium. These two surfaces will tend to heal together and form a web (i.e., restenosis). A stent or a keel that separates these two denuded areas is necessary to prevent this problem. Alternatively, the web can be divided into superficial and deep layers based laterally at the anterior one third of the free edge of the true vocal folds. These flaps are then rotated to cover the denuded areas of the cord, thereby precluding the need for a keel.

Anterior glottic webs less than 1 cm in height are amenable to endoscopic excision. The patient is placed in a supine position and the neck is hyperextended with a shoulder roll. A wide direct laryngoscope that allows binocular microscopic magnification is suspended in place after the lesion is adequately exposed. The web may be lysed with a laser or "cold" microsurgical instruments (Fig. 45-10A to C).

During CO_2 laser surgery, the safety of the patient and operating room personnel is a primary consideration. All operating room personnel should use protective eyewear. The eyes of the patient are kept closed with adhesive dressing (e.g., Tegaderm) and then covered with eye pads soaked in saline solution. The face, upper part of the chest, and the laryngoscope are covered with surgical towels soaked in saline solution (Fig. 45-11). The endotracheal tube, exposed outside the mouth, should be covered with metal tape or foil. In the airway the tube is protected with wet cottonoid. All these maneuvers complement but are not a substitute for good judgment and careful surgical technique. Before commencement of the surgery, the laser should be tested to ensure that the aiming beam is aligned (i.e., coaxial) to the laser beam. "Bouncing" of the laser beam against the laryngoscope during surgery should be avoided. Similarly, the laser beam should not be allowed to hit the subglottis when the surgeon is working at the free edge of the cord to avoid unwarranted damage to the subglottis and increase the possibility of inadvertent endotracheal tube puncture and fire. The subglottis may be protected with cottonoid soaked in normal saline solution or by using a nonreflecting platform below the free edge of the cord receiving the laser beam. Laser char is removed frequently with pledgets soaked in normal saline solution. Anterior webs usually require low power (e.g., 4 to 6 W) for vaporization and hemostasis.

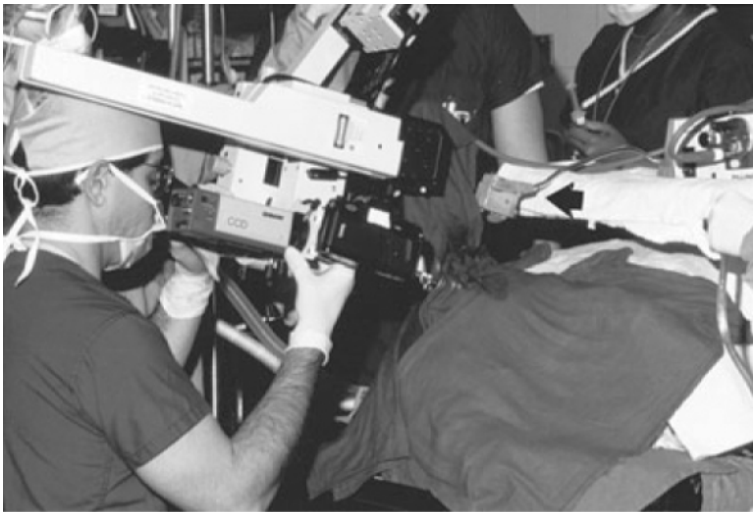

Figure 45-11 Setup for laser microsurgery. The patient and the laryngoscope are covered with towels soaked in normal saline solution. The *arrow* indicates the suspension system.

When "cold" microsurgical instruments are used, hemostasis is achieved with a topical 1:10,000 adrenaline solution applied with a 0.5 × 0.5-inch neurosurgical pledget. It is important to remember that adrenaline will be absorbed into the circulation immediately. The recommended maximal dosage should be observed, and anesthesia personnel should be notified before applying the solution. The web is transected with up-biting microscissors, and granulation tissue is removed with microcup forceps. Topical application of mitomycin C (a 0.4-mg/mL solution for 4 minutes) reduces scarring and may decrease the probability of recurrence.

On lysis of the web, a stent is placed endoscopically and secured in place with transcutaneous monofilament suture (Fig. 45-12). The stent is left in place for 10 to 14 days, after which the patient is taken back to the operating room for removal of the stent and inspection of the surgical site.

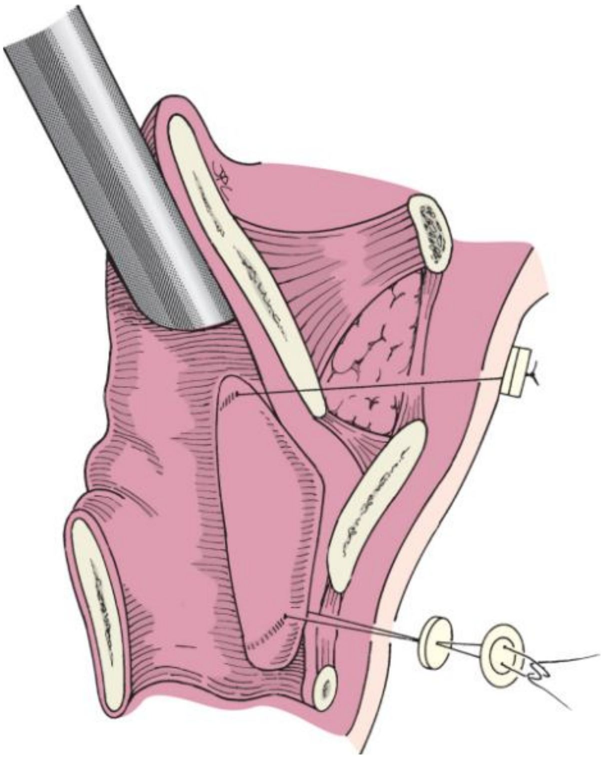

Figure 45-12 Sagittal plane. An anterior glottis keel is inserted and secured with external monofilament (transcutaneous) sutures.

Webs thicker than 1 cm, those involving the subglottis, and those associated with posterior glottic stenosis may require a laryngofissure approach (see Chapter 42). A silicone Montgomery umbrella is left in place after the web is divided (Fig. 45-13). This prosthetic device remains in place for 2 to 4 weeks. The optimal time for removal is when the anterior one third of the true vocal cords shows complete epithelialization, which may be ascertained by flexible laryngoscopy. Removal of the stent requires opening the incision with the patient under local anesthesia and can be done in the office.

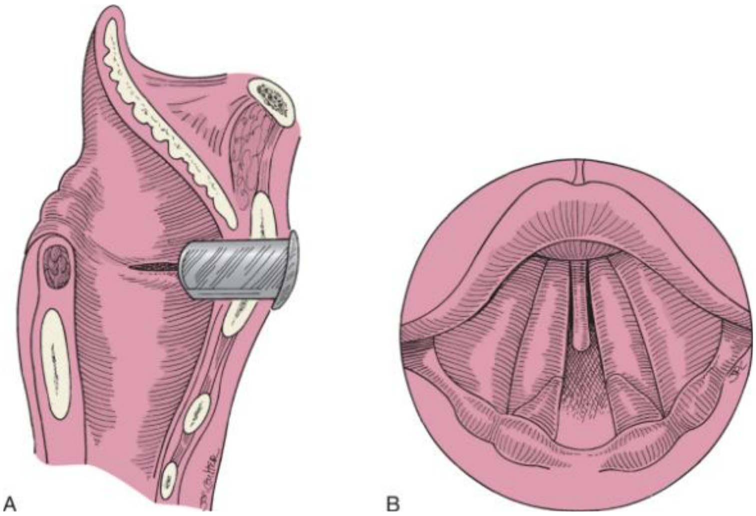

Figure 45-13 **A**, Sagittal plane. Montgomery's umbrella is in place after lysis of an anterior glottic web via laryngofissure. **B**, Axial plane. The anterior keel is in place.

Loss of the anterior segment of the thyroid cartilage as a result of trauma or oncologic surgery requires reconstruction of the cartilaginous support. The preferred method for such reconstruction is the epiglottopexy laryngoplasty described by Kambic and associates.[46] This procedure involves a transcervical approach, similar to the one described for a laryngofissure (see Chapter 42). When feasible, the thyroid cartilage is transected at the midline, although the midline may be difficult to establish in the presence of scarring. In these cases the midline of the anterior commissure may be estimated through the direct laryngoscope, before the transcervical procedure is started. In most cases, however, this point is moot, because severe scarring and loss of tissue mandate reconstruction of the entire anterior laryngeal anatomy. The thyrohyoid membrane is incised between the lesser cornua to expose the superior preepiglottic space. The anterior surface of the epiglottis is dissected from the soft tissue of the preepiglottic space. The petiole of the epiglottis is then grasped and retracted inferiorly to facilitate lysis of the median and lateral epiglottic ligaments (Fig. 45-14A). Continuity of the lateral and superior mucosa with the base of tongue and vallecula should be preserved (Fig. 45-14B).

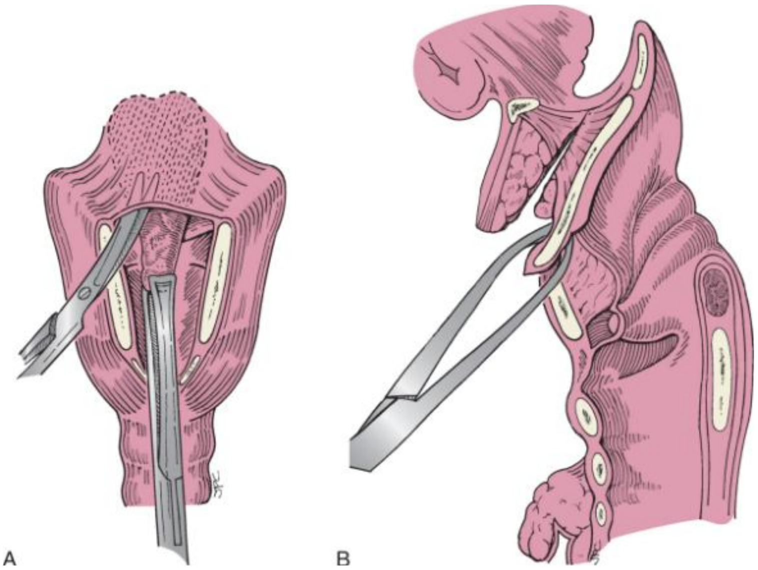

Figure 45-14 Coronal (**A**) and sagittal (**B**) views. The petiole of the epiglottis is retracted inferiorly to facilitate dissection of the lingual surface of the cartilage from the surrounding soft tissue.

A Montgomery laryngeal stent is placed and secured with transcutaneous, transcervical monofilament suture. Alternatively, an Eliachar laryngeal stent may be used. The epiglottic cartilage is split in the midline while preserving the mucosa of the laryngeal surface of the epiglottis to produce a sharp-angled anterior commissure (Fig. 45-15). The lateral edges of the epiglottis are sutured to the anterior edges of the thyroid ala with interrupted absorbable suture. The petiole is also sutured, usually to the superior margin of the cricothyroid membrane. Occasionally, the petiole may be mobilized low enough to augment the anterior cricoid arch, which may be necessary if the anterior subglottic stenosis involves the cricoid cartilage. The strap muscles are approximated, and the wound is closed in multiple layers. A soft rubber drain (e.g., Penrose) is left in place, and a compressive dressing is applied.

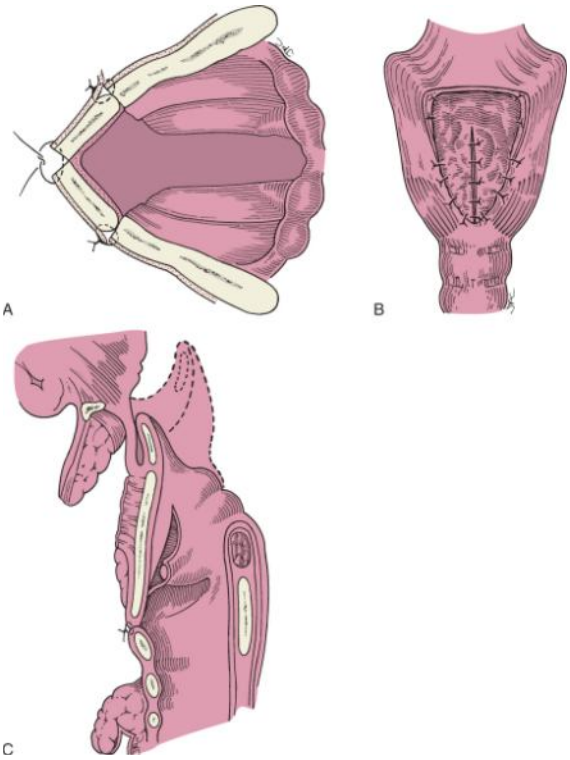

Figure 45-15 Axial (**A**), coronal (**B**), and sagittal (**C**) views. Reconstruction of the anterior thyroid cartilage has been completed. The epiglottic cartilage has been divided, with sparing of the mucoperichondrium on the laryngeal side of the epiglottis to re-create the V-shaped apex of the anterior commissure.

This technique has the advantage of providing immediate reconstruction of the infrastructure, as well as the endolaryngeal lining, with local vascularized tissue, thereby expediting healing. Although the reconstruction is completed in one stage, the patient must be returned to the operating room for transendoscopic removal of the stent. This technique also has the disadvantage of a tendency to produce a round anterior commissure, even with the described method (Fig. 45-16).

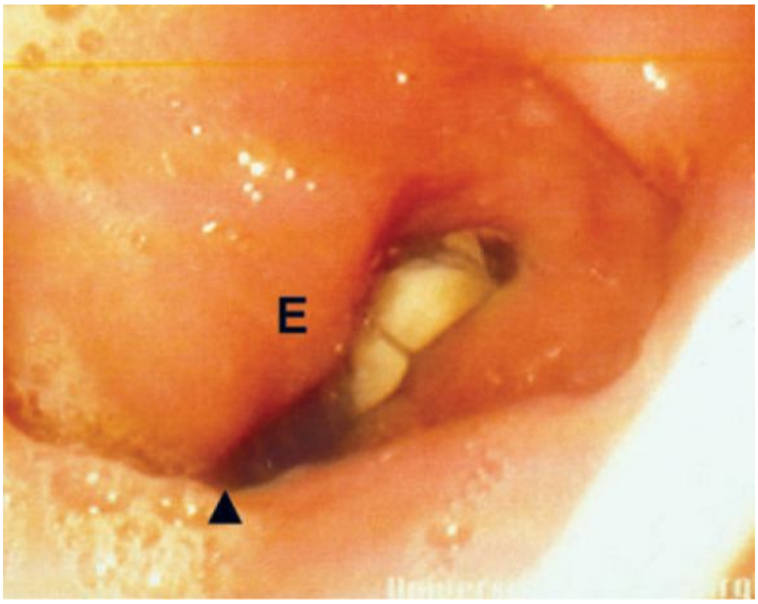

Figure 45-16 The endolarynx after Kambic's procedure for reconstruction of a glottic stenosis after right hemilaryngectomy. Notice the convex shape of the epiglottis (E). The *arrowhead* indicates the anterior commissure.

Posterior Glottic Stenosis

Posterior glottic stenosis is most commonly the result of interarytenoid scarring secondary to prolonged endotracheal intubation or trauma. Regardless of the method or refined surgical technique, the success of the surgery depends on the degree and depth of the scarring. For example, a posterior glottic mucosal web is easier to correct and has a much better prognosis than does scarring that resulted from necrosis of the interarytenoid muscles. In fact, the possibility of providing a long-term functional solution to the latter problem is low. Another important factor is the mobility of the cricoarytenoid joints. If the joints are fixed, lysis of scar tissue will not restore an adequate airway.

The preferred method for reconstruction of posterior stenosis caused by mucosal scarring is excision of the scar through a microtrapdoor flap, as described by Dedo and Sooy.[33] An inferiorly based flap is elevated from the interarytenoid area with the laser or, preferably, with microsurgical instruments. The submucosal scar is removed, and passive mobility of the arytenoids is tested. The flap is repositioned over the operated area to promote primary healing (Fig. 45-17).

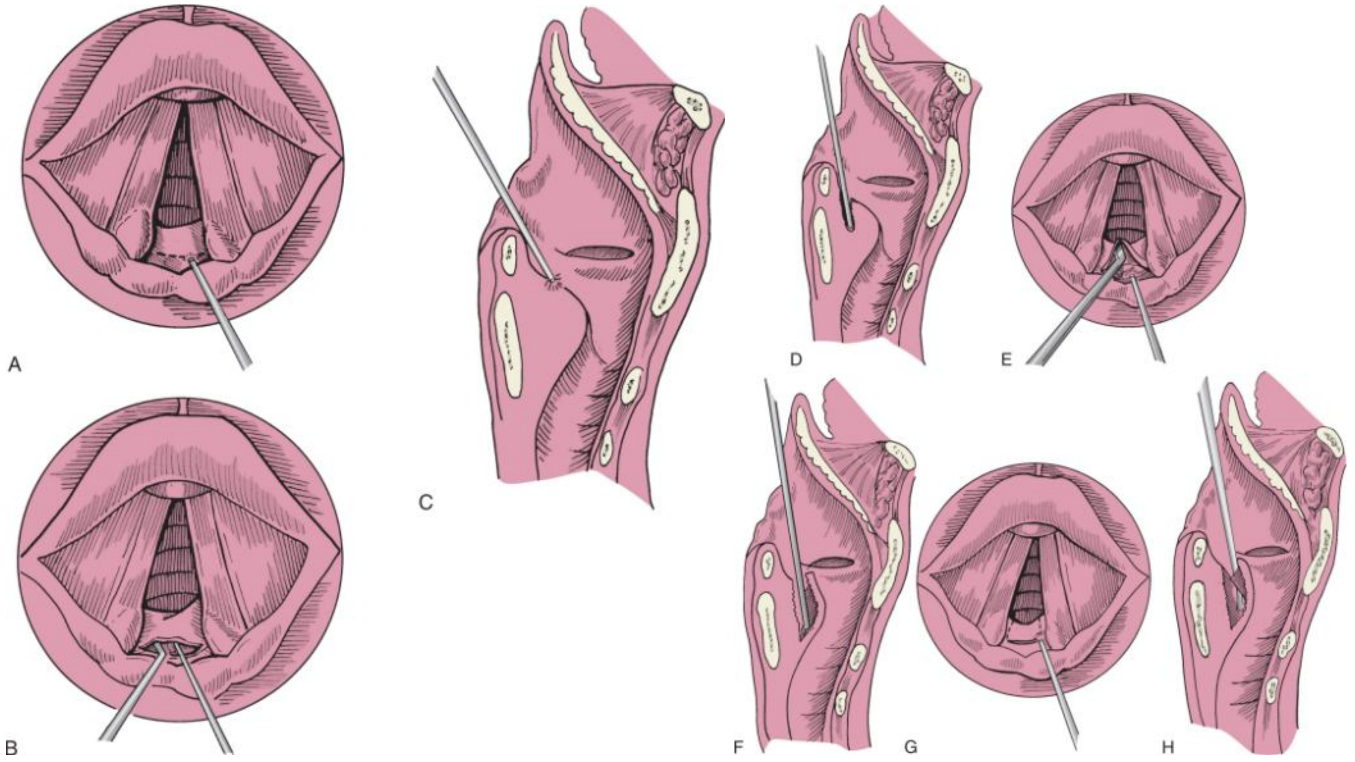

Figure 45-17 **A** to **H**, Microtrapdoor flap to remove a posterior glottic web. Submucosal scar resection is completed with microsurgical instruments or laser vaporization while taking care to spare the overlying mucosa.
(From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, pp 498-499.)

When one arytenoid is fixed, mobilization is attempted by displacing the base of the vocal process in a lateral direction and rocking the arytenoid repeatedly in all axes. This maneuver has to be performed with utmost care to avoid fracturing the vocal process.

When mobilization of the arytenoid cartilage is not possible, a medial arytenoidectomy is performed either by endoscopic laser microsurgery or transcervically through a laryngofissure or Woodman's approach. The latter is more difficult to perform, but the mucosa is preserved and postoperative recovery is faster (see Chapter 38), although the entire arytenoid is removed and the patient is left with an increased risk for aspiration. An alternative to arytenoidectomy is posterior cordotomy.

When the microtrapdoor flap fails but the arytenoids are mobile or when the posterior stenosis involves the interarytenoid musculature, maximal scar release may be achieved via laryngofissure. Mucosal coverage is then provided with a hypopharyngeal advancement flap, which involves less sacrifice of voice quality and less potential for aspiration than noted with transendoscopic laser arytenoidectomy.

Subglottic Stenosis

Acquired subglottic stenosis may be segmental or secondary to collapse or webbing or may involve the entire circumference of the lumen. The corrective procedure should strive to address the involved area while preserving the adjacent normal tissue.

Thin webs are amenable to excision via endoscopic microsurgery. (A subglottoscope is very useful to visualize the full extent of the lesion.) Wedge excision of the mucosal web at every quadrant or radial incisions augment the airway and preserve enough epithelium to prevent restenosis (Fig. 45-18).

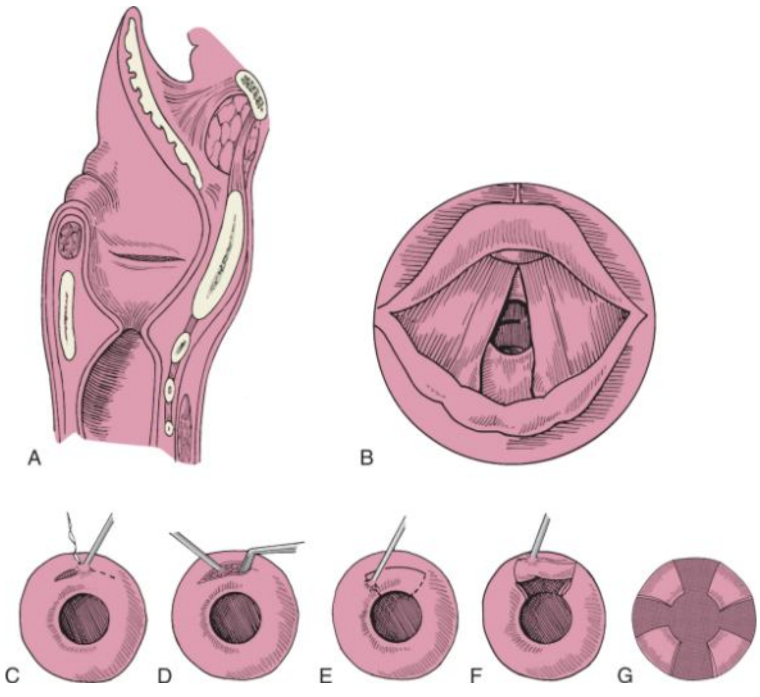

Figure 45-18 **A**, Sagittal view of circumferential subglottic stenosis. **B** to **G**, Tracheal lumen after laser excision of a wedge-shaped area at four quadrants. It is not essential to excise four wedges; two or three wedges may be adequate for some patients.
(B to F, From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 509.)

When the stenosis is recurrent or when it is thicker than 1 cm, an external approach and augmentation procedure are necessary. Cartilage from the septum, thyroid ala, or rib may be harvested for use as a free graft. We prefer the latter because it is abundant, thicker, and easier to carve.

A horizontal incision is performed in a skin crease over the cricoid cartilage. Subplatysmal flaps are elevated to expose the thyroid notch and upper trachea. The strap muscles are separated in the midline to expose the laryngotracheal complex. A midline cricoidotomy is performed and extended into the upper two tracheal rings. The cricothyroid membrane is opened horizontally to facilitate lateral retraction of the cricoid chondrotomy segments. The mucosa is incised to expose the posterior mucosal surface of the larynx and trachea. A posterior cricoid chondrotomy is performed while preserving 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. 45-19). Kirschner wires are passed into the graft to fix it in place.[47] The same maneuver is used anteriorly.

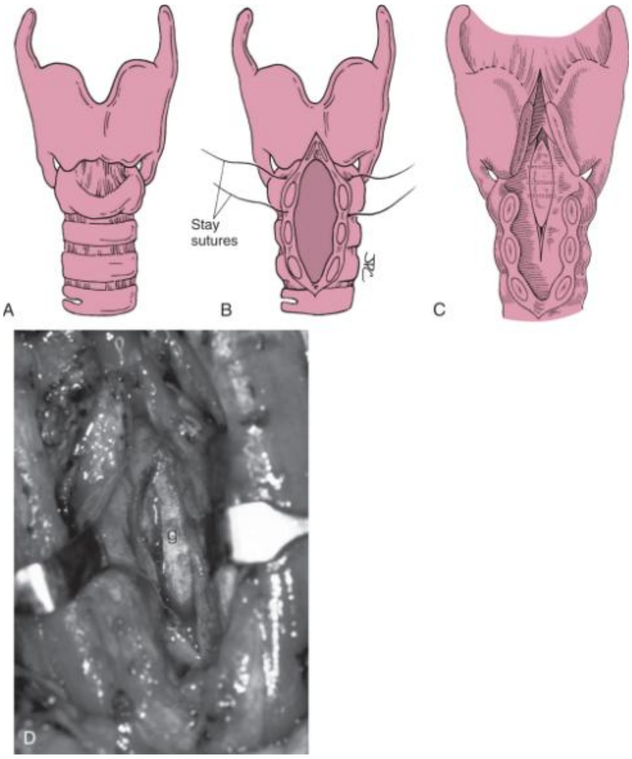

Figure 45-19 **A** to **D**, Free cartilage graft (spindle shaped) to the posterior cricoid. The graft (g) is secured with Kirschner wires.
(A and B, From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 467.)

A rigid fixation plate may be used to fix the anterior graft in place, which has been carved in a lock-and-key fashion, as described by Zalzal and Cotton (Fig. 45-20).[48] Alternatively, Kirschner wires (24 gauge) can be passed through the cartilage graft and inserted through the cartilage of the receiving site (Fig. 45-21). The ends of the wires are then bent and secured in place with 28-gauge wire (Fig. 45-22). 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.

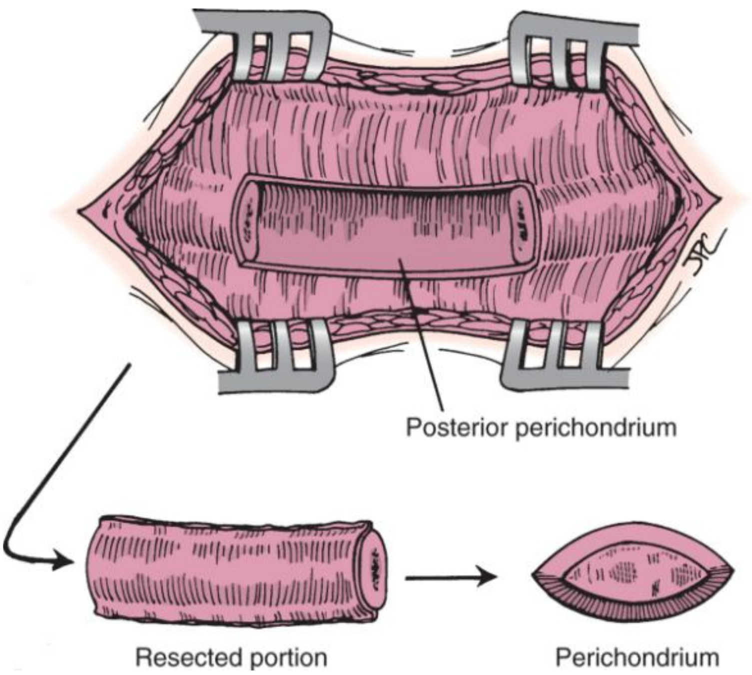

Figure 45-20 Rib cartilage is carved to fit the anterior chondrotomy, as described by Zalzal and Cotton.[48]
(From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 470.)

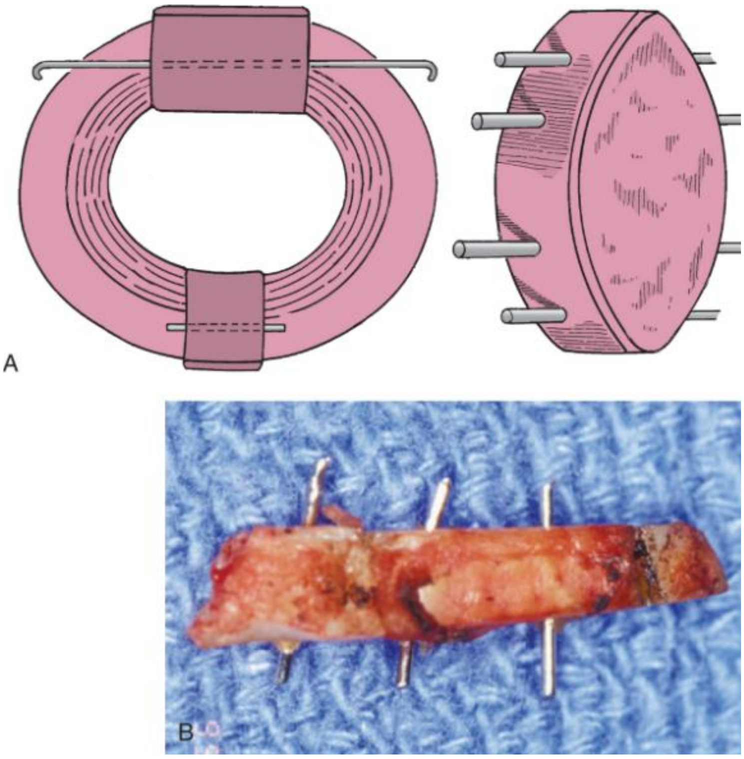

Figure 45-21 **A**, Placement of wires through the free cartilage graft. An axial view of the anterior and posterior cartilage shows the graft in place. **B**, Placement of wires through the free cartilage graft.

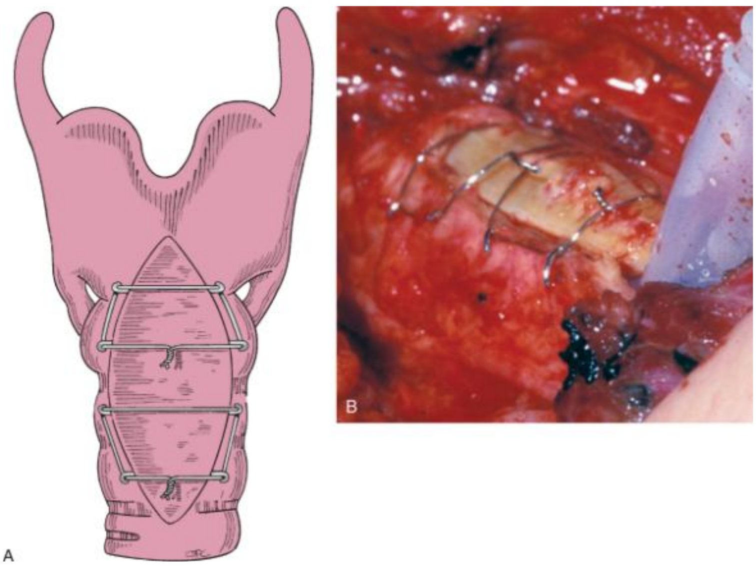

Figure 45-22 Illustration (**A**) and clinical photograph (**B**) demonstrating the wiring technique on a free cartilage graft to reconstruct an anterior tracheal defect.

A sternocleidomastoid myoperiosteal flap, as described by Friedman and Colombo, is an alternative technique for augmentation of the anterior cricoid ring and cervical trachea.[49] The surgical approach and exposure are similar to those already described. The sternoclavicular origin of the left sternocleidomastoid muscle is exposed through the cervical incision and mobilization of subplatysmal flaps (Fig. 45-23). 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. The clavicular periosteum around the clavicular insertion is incised and elevated as a myoperiosteal flap (Fig. 45-24). This flap is mobilized into the defect until tension-free closure can be achieved (Fig. 45-25). The flap is then sutured to the anterior edges of the cricoid and trachea over a Montgomery ┬ tube (Figs. 45-26 and 45-27). A soft rubber drain is left in place. The wound is closed in multiple layers, and a compressive dressing is applied.

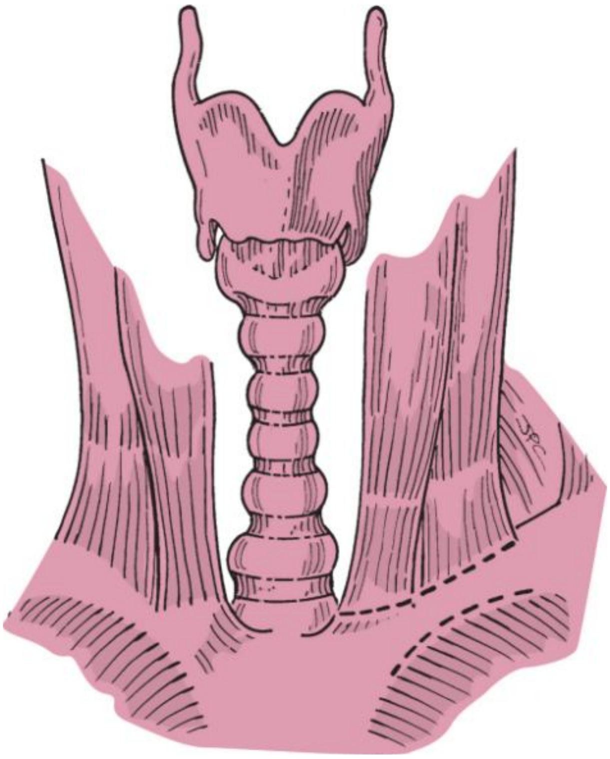

Figure 45-23 Surgical exposure of the sternoclavicular head of the sternocleidomastoid muscle and the area of the stenosis.

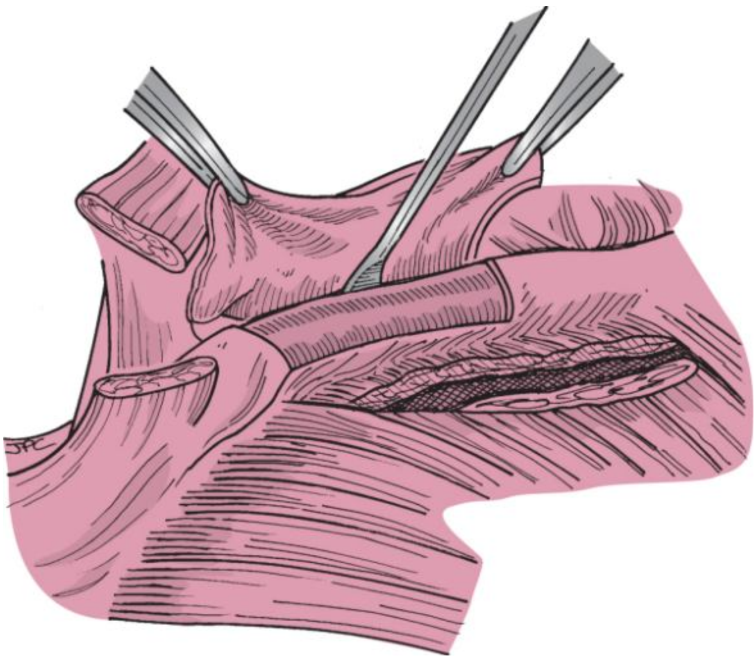

Figure 45-24 The periosteum is elevated en bloc with the sternoclavicular head of the sternocleidomastoid muscle.

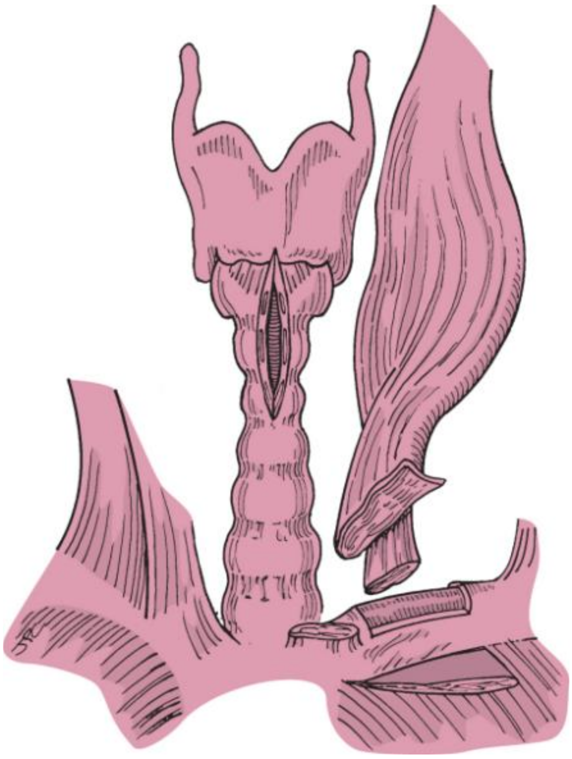

Figure 45-25 The myoperiosteal flap is elevated. Branches of the thyrocervical trunk supplying the inferior aspect of the sternocleidomastoid muscles are usually sacrificed to enhance mobility of the flap.

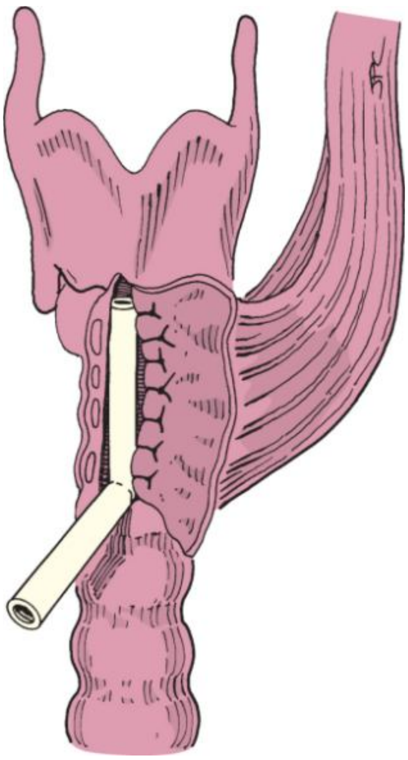

Figure 45-26 The myoperiosteal flap is sutured to the defect. A Montgomery ┬ tube maintains the shape of the lumen and secures the airway.

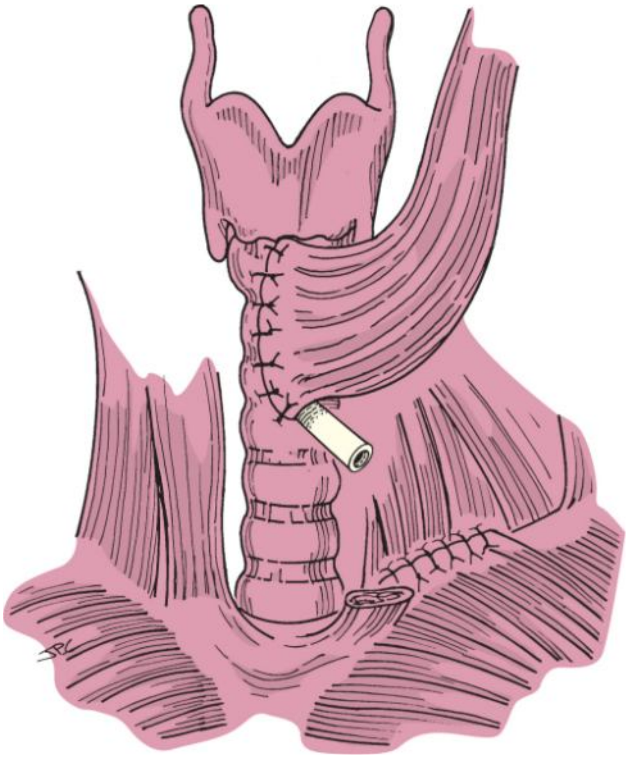

Figure 45-27 The myoperiosteal flap has been sutured to the defect.

Subglottic Stenosis in the Pediatric Population

Anterior Cricoid Split

Indications for an anterior cricoid split now include the management of mild anterior subglottic stenosis in neonates and infants. Before any patient is considered for this operation, the stenosis should be corroborated by direct endoscopic visualization and at least two attempts at extubation should have failed. The patient's weight should be greater than 1500 g, mechanical ventilation or supplemental oxygen greater than a fractional inspired oxygen concentration (FIO_2) of 35% should not be needed, the patient must be free of lower respiratory infection or congestive heart failure for 30 days before the operation, and antihypertensive medications should not be required.[49]

If the patient meets these criteria, the endoscopy and anterior cricoid split may be performed as a single-stage operation. It is essential that other causes of obstruction that may be interfering with extubation be ruled out during endoscopy because they may influence the therapeutic plan. After endoscopy, ventilation is continued through the bronchoscope, or if feasible, an endotracheal tube is placed. The neck is prepared and draped with sterile technique. A horizontal incision following a midneck crease is performed and extended through the subcutaneous tissue and platysma. Subplatysmal flaps are elevated to expose the area corresponding to the entire laryngotracheal complex. The strap muscles are dissected in the midline to expose the thyroid and cricoid cartilage and the upper trachea. The cricoid cartilage and the first two tracheal rings and underlying mucosa are divided in the midline. Monofilament stay sutures are placed on both sides of the trachea to facilitate pulling the split laryngotracheal complex to the surface of the wound (Fig. 45-28). The inferior one half of the thyroid cartilage is incised at the midline, but the mucosa and anterior commissure are left intact. An endotracheal tube is used as a stent. The patient is kept under heavy sedation in an intensive care unit for 7 to 10 days. Extubation is attempted in the operating room so that the patient can be reintubated if the airway is still compromised.

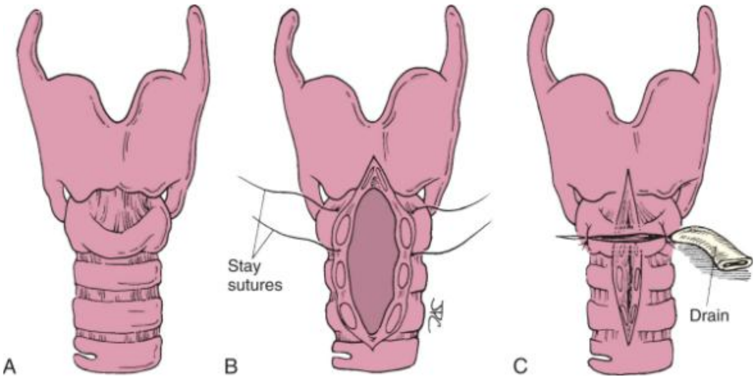

Figure 45-28 **A** to **C**, Anterior cricoid split.
(From Bluestone CD, Stool SE [eds]: Atlas of Pediatric Otolaryngology. Philadelphia, WB Saunders, 1995, p 467.)

Laryngeal Augmentation

Laryngeal augmentation for subglottic stenosis can be achieved by anterior or posterior cricoid grafting or by a combination of the two. Anterior augmentation is usually recommended for moderate stenosis not associated with significant loss of cartilage or glottic stenosis. Posterior augmentation is most useful when the subglottic stenosis is associated with posterior glottic stenosis. Nevertheless, a posterior graft is rarely used alone. Glottic-subglottic combined stenosis is often corrected with both anterior and posterior grafts, which are most commonly harvested from rib cartilage.

POSTOPERATIVE CARE

Patients are transferred to an intermediate or intensive care unit for continuous monitoring and frequent tracheotomy care. The head of the bed is kept elevated 30 degrees to diminish the possibility of gastric reflux and to facilitate ventilation. Humidified air is administered by face or tracheotomy mask, according to the circumstances. Delivery of oxygen through hoses with a T attachment of the tracheotomy tube is not recommended because they exert traction on the tracheotomy tube and elicit pain and cough. Furthermore, such 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 endolaryngeal repair. A nasogastric tube for suctioning of stomach contents during the initial postoperative period and subsequent feeding is recommended.

The tracheotomy tube may be downsized or changed to a cuffless tube no less than 72 hours after the procedure. This allows the formation of a tract, which greatly facilitates insertion of the second tube. Nevertheless, in most cases the tracheotomy tube is not changed until the patient can swallow saliva and is not showing signs of aspiration. 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 tracheotomy tube should not be removed until a patent and competent airway is secured. In other words, the patient should be able to breathe and protect the airway from aspiration before the tube is removed. Clinical signs such as the ability to tolerate a plugged tube and the absence of bronchorrhea, choking, or other signs of aspiration suggest that the patient is ready to be decannulated. A flexible laryngoscope is an invaluable adjunct to ascertain the 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 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, the companions should be taught how to remove the stent and insert a tracheotomy tube.

COMPLICATIONS

Airway

The most dreaded complication after any kind of laryngeal surgery is loss of the airway. Airway compromise may ensue secondary to edema or hematoma within the soft tissues of the larynx, as in patients managed with endolaryngeal surgery without a tracheotomy, or may be due to plugging or accidental decannulation of the tracheotomy tube or ┬ tube. The old dictum that prevention is the best treatment is most applicable during laryngeal surgery. Preventive measures have been addressed throughout this chapter.

Patients in whom airway compromise develops after undergoing laryngeal surgery without a tracheotomy will benefit from humidified oxygen and should be provided with a surgical airway. A tracheotomy is preferable to a cricothyroidotomy because the latter may produce more subglottic scar tissue and possibly complicate future management of the primary stenosis. Nevertheless, if an emergency airway is needed, cricothyroidotomy is the most expedient procedure. A mixture of 70% helium and 30% oxygen may be used as a temporary measure. Helium is less dense than nitrogen and flows with less friction and turbulence, thus diminishing the respiratory workload. Select patients can be managed with corticosteroids, racemic epinephrine, and humidified oxygen or heliox, under close monitoring, until the swelling resolves.

A plugged tracheotomy tube is managed by removing the inner cannula, which may produce a patent outer cannula, by displacing or perforating the plug with a suction catheter, or ultimately, by removing and replacing the tracheotomy tube. During the early postoperative period, reinsertion of the tracheotomy tube after accidental or therapeutic decannulation is facilitated by traction on the stay sutures (see Chapter 68). The stay sutures bring the tracheal window close to the skin and thus provide better visualization of the opening and prevent a false passage. A suction catheter or endotracheal tube introducer may be used as a guide if the stay sutures break or the patient has a very thick neck that impairs direct visualization of the tracheal window. If a flexible laryngoscope or bronchoscope is rapidly available, it provides direct visualization of the trachea and is a safer guide than any rubber catheter.

Plugging of a ┬ tube stent with mucus deserves special consideration because it does not have the safety mechanism provided by a double cannula. Even if the mucous plug can be displaced or perforated with a suction catheter, patency of the tube should be ascertained by direct examination with a flexible scope. If the mucous plug cannot be removed with help of the laryngoscope, the ┬ tube should be removed and replaced with a tracheotomy tube, inserted as previously described. The ┬ tube stent can be reinserted after the airway is stabilized. Nevertheless, in the early postoperative period, reinsertion has to be undertaken with the patient under general anesthesia and guided by visualization through a direct laryngoscope.

Subcutaneous Emphysema

Subcutaneous emphysema may be massive and associated with pneumomediastinum, which in infants may produce respiratory compromise. In adults, subcutaneous emphysema, though unsightly, is of limited significance. Subcutaneous emphysema is the result of insufflation of air into the soft tissues through a laryngeal wound during exhalation. The air is usually reabsorbed without consequence. Nonetheless, it has to be remembered that this air may also be accompanied by secretions (i.e., contamination), so antibiotics are recommended to prevent wound infection.

Infection

Adequate wound drainage is of utmost importance for the prevention of infection. The drain should be kept in place until the tissue flaps have healed suficiently to prevent accumulation of fluid. A soft rubber drain (e.g., Penrose) should be advanced slowly before removal. Suction drains should be maintained until drainage is minimal.

A postoperative wound infection may or may not be associated with a laryngocutaneous fistula. In any case, the most significant factor influencing the outcome of any wound infection is adequate wound drainage. If the rubber drain is still in place, it should be retained until it yields minimal or no drainage; only then may it be advanced and removed. Systemic antibiotics with a wide spectrum against oral flora (e.g., clindamycin) are administered to prevent sepsis.

PEARLS

- Intraoperative control of the airway by either endotracheal intubation or tracheotomy is paramount in any surgery for laryngotracheal stenosis.
- Dilatation can be successfully used as primary treatment of select cases of thin congenital webs, as adjuvant therapy for endoscopic microsurgical techniques, or as palliation in patients who are medically unsuited for major reconstructive surgery.
- Endoscopic microsurgical techniques, with or without adjunctive procedures such as intralesional steroid injection or application of mitomycin C, are ideally suited for the management of thin webs or other less severe stenoses with good cartilage support.
- Anterior glottic webs less than 1 cm in height are usually amenable to endoscopic excision with subsequent placement of a stent or keel.
- Posterior glottic stenosis is often successfully managed by scar excision through a microtrapdoor flap; however, success of surgery depends on the degree and depth of scarring, as well as the mobility of the cricoarytenoid joints.

PITFALLS

- Endoscopic microsurgery for acquired laryngeal 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 is wider than 1 cm, when the lesion is circumferential, and when accompanied by the presence of bacterial infection.
- Failure to control gastroesophageal reflux in the perioperative period may contribute to recurrent or persistent laryngeal stenosis.
- In the office setting, passing a flexible scope through a significant laryngeal stenosis may lead to airway compromise and a clinically unstable situation.
- Changing to a cuffless tracheotomy tube too soon after laryngotracheal reconstruction may lead to subcutaneous emphysema, contamination of the cervical wounds, and even a laryngocutaneous fistula.
- A persistent postoperative laryngocutaneous fistula usually signifies inadequate wound drainage and underlying infection.