

Obstructive Lesions of the Pediatric Subglottis

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ABSTRACT

Purpose: To compile information regarding obstructive subglottic lesions in children, including anatomy, pathogenesis, prevention, evaluation, and treatment options, required for implementation of a multi-faceted treatment plan.

Method: Review of the literature.

Conclusions: Although they are infrequent, obstructive subglottic lesions pose significant challenges to treating physicians, from airway management and injury prevention to decannulation and voice rehabilitation. Most patients with these lesions require multidisciplinary care and long-term treatment and can nearly always be treated successfully.

INTRODUCTION

The pediatric airway has gained a notorious reputation among physicians who treat children as being tenuous and often difficult to manage. The airway arises from a complex embryologic development and is prone to compromise from multiple sources and at multiple levels. The proper management of pediatric airway obstruction is of paramount importance, initially as a lifesaving measure, and subsequently in the establishment of a self-sustaining airway with good prospects for normal speech development.

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Obstructive lesions of the pediatric airway can occur at any level, from the nose and nasopharynx, through the pharynx and supraglottis, to the glottis, subglottis, trachea, and lower airway structures. At any level the lesions can be congenital or acquired; expansile, dynamic, or static; and partially to progressively to completely obstructive.

The subglottis is a particularly injury-prone area in the neonatal and pediatric populations because it is a major point of contact for the life-saving measures provided by endotracheal intubation. In this text, obstructive lesions of the pediatric subglottis will be divided into neoplastic lesions, subglottic hemangioma, and subglottic stenosis. The presentation, evaluation, diagnosis, and treatment of each type of lesion will be discussed.

EMBRYOLOGY AND ANATOMY OF THE SUBGLOTTIS¹⁻⁴

The initial event in laryngeal development occurs when the embryo is just 2 mm in length, with the appearance of a median pharyngeal groove as the precursor to the primitive foregut. By Day 25, a ventromedial diverticulum emanates from the upper foregut that will soon form the tracheobronchial tree and lung buds. Lateral processes begin to form that will fuse in the midline, dividing the trachea and esophagus. At 33 days, the primordial epiglottis and arytenoid cartilage precursors form from the mesenchymal portions of pharyngeal arches 3/4 and 6, respectively. The cricoid ring is complete around 7 weeks of development, and formation of the rest of the laryngeal cartilages is well under way by this point. The larynx, trachea, and esophagus are fully formed organs by 12–13 weeks, with evidence of primitive function following canalization by resorption and expansion of endodermal tissues.

The fetal phase of laryngeal development is marked by fetal “breathing,” in which amniotic fluid is circulated into the airway, as well as by swallowing through the esophagus. Both are important for the development of distal structures and for the refinement of laryngeal function. Therefore, failure of canalization results not only in airway obstruction from laryngeal atresia, but also in pulmonary and

alimentary underdevelopment. This fetal phase also sees further differentiation of the epithelium of various portions of the larynx into respiratory and squamous epithelium and the formation of goblet cells.

At birth, the larynx is very different in form and function than its adult counterpart. The cricoid originally rests at the level of C2 but descends to C5 at 2 years of age and to C6 by 5 years of age. The adult cricoid is fully descended at C6/C7 at approximately 15 years of age.⁵ The neonatal thyroid cartilage is proportionally shorter and wider than in the adult larynx, and the cricoid is proportionally smaller. This results in a funnel shape to the laryngeal airway. In addition, the subglottic submucosa has a larger proportion of glandular soft tissue than the rest of the airway, making it the narrowest part of the neonatal airway as opposed to the glottis in the adult. Other differences include increased compliance of the thyroid cartilage of the young larynx and its immature neuromuscular reflexes, which predispose neonates to certain levels of aspiration, particularly of reflux fluid.

The subglottis is defined as the portion of the airway bounded superiorly by the junction of squamous and respiratory epithelia, a few millimeters below the free edge of the true vocal fold, and inferiorly by the inferior edge of the cricoid cartilage. It is bounded on all sides by the cricoid ring, which forms the only completely enclosed ring in the entire airway and is an important contributor to the development of obstructive lesions.⁶ The thyroid and tracheal cartilages do not form complete rings and therefore have potential for physiologic expansion, at least theoretically. The complete ring of thick cricoid cartilage is unforgiving in the face of airway compromise, further heightening the urgency of airway considerations when dealing with lesions of the subglottis.

CONSIDERATIONS IN SUBGLOTTIC OBSTRUCTION

The first and most important concept to remember when dealing with subglottic obstruction is ensuring that a safe and adequate airway is maintained at all times. This is paramount to any other considerations in the face of airway obstruction and should be maintained at the forefront of all evaluations and prospective treatments.

An important point to remember in the treatment of subglottic lesions is the risk of a cicatricial injury. The airway is a tube lined by a mucosal surface that reacts to injury through inflammation, which may result in scarring. In the event that a circumferential or nearly circumferential injury occurs in the airway, a corresponding scar may form, thereby narrowing the airway and producing an iatrogenic airway stenosis.

Finally, the effects of a narrowed airway are an extremely important issue when understanding the evaluation and treatment of patients with airway lesions. Flow through any enclosed tube is governed by Poiseuille's Law:

$$Q = \frac{\pi r^4 P}{8\eta L}$$

Where Q = flow through the tube, r = radius of the tube, L = length of the tube, and η = viscosity of the flow material.

One can see from the equation that flow (Q) is directly proportional to the radius of the tube to the *fourth power*. This means that an incremental change in the radius of the tube will change the flow rate exponentially. Indeed, it has been found that a 1 mm decrease in the diameter of the neonatal subglottis, which is normally 4 mm, results in as much as a 60% decrease in airflow. Another effect of a narrowed airway is the increased risk of injury resulting from intubation or surgery. When already narrowed, the space available within the subglottic lumen cannot accommodate an injury as well.

EVALUATION OF SUBGLOTTIC OBSTRUCTION

The cardinal presenting symptoms for subglottic obstructive lesions are stridor and failure to extubate. There is great variety, however, in how these patients present, from a neonate who has failed extubation twice since birth, to a 4-year-old with poor exercise tolerance. Key points in the history focus on predisposing factors including intubation history, perinatal hospital course, syndromic considerations, progression of breathing difficulties, and the duration, character, and severity of symptoms.

The physical examination begins with an evaluation of the general state of the patient, with particular attention to the respiratory status. Retractions, stridor, air hunger, and skin color, along with vital signs should alert the physician to any need for an urgent or emergent airway intervention. A full head and neck examination and airway evaluation follow, along with auscultation of the chest and neck to potentially localize the obstruction. Facial skin lesions should be noted. Patients who are stable may undergo flexible fiberoptic laryngoscopy to evaluate the glottis for vocal cord pathology, including paralysis and involvement of the vocal cords by the primary lesion. Also, for the stable patient, A-P and lateral neck films may assist in diagnosis, as may magnetic resonance imaging and dynamic airway fluoroscopy.

The most critical part of the evaluation in patients with subglottic lesions is the rigid endoscopy. This procedure begins with evaluation of the supraglottis

Table 1. Tumors of the Subglottis

Benign	Malignant
Granular cell tumors	Rhabdomyosarcoma
Fibrous histiocytoma	Mucoepidermoid carcinoma
Papilloma	Malignant fibrous histiocytoma
Neurofibroma	Adenoid cystic carcinoma
Pleomorphic adenoma	Squamous cell carcinoma
Hemangioendothelioma	Carcinoid
Neurilemoma	

and the vocal cords for paralysis or arytenoid fixation. Diagnosis of the subglottic lesion and further evaluation of the airway can then be performed to rule out multiple airway lesions that may contribute to the obstruction. The size, length, and consistency of the lesion should be noted, as well as appropriate endotracheal tube sizes if needed. Treatment may often be initiated at the time of the first endoscopic evaluation.

SOLID SUBGLOTTIC TUMORS

Tumors of the subglottis are very rare. Hemangioma, by far the most common type, will be discussed separately. However, there is an extremely diverse set of neoplastic lesions that occur in the subglottis, ranging from salivary tumors to epidermal carcinomas to sarcomas. Table 1 shows a list of tumors that may occur in the subglottis, but this list is not exhaustive. Overall, tumors of the subglottis are 64% benign and 36% malignant.⁷ They present with a highly variable combination of hoarseness, stridor, obstruction, and even hemoptysis, with a highly diverse range of prognoses.

As with any other obstructive subglottic lesion, the treatment often begins with securing the airway, along with endoscopic evaluation and biopsy of the mass. Lesions may then be removed by one of several methods that will be further discussed in later portions of this text. Methods for removal include endoscopic excision, laryngotracheofissure, or cricotracheal resection. Some of these tumors, such as papilloma, require repeated treatments, and some require multimodal treatments such as radiation or chemotherapy. Because these tumors are exceedingly rare, and because their evaluation and treatment are analogous to that of more common lesions, they will not be further discussed here.

SUBGLOTTIC HEMANGIOMA (SGH)

Hemangiomas are the most common tumors in the infant airway. Composed of poorly organized vascular structures amid a moderately cellular fibrous

stroma, these masses follow a distinct natural history. They are not evident at birth but enter a rapid proliferative phase beginning 2 to 6 months after birth, usually lasting 6 months to one year. After this period, hemangiomas begin an involution phase that can be highly variable in length. Early responders, representing 50% of patients with hemangiomas, have complete involution by 5 years of age, and late responders have complete involution between 10 and 12 years of age. As the child gets older and the hemangioma persists, chances of involution decrease, with a small proportion halting prior to complete involution.⁸ There is a 2 to 1 female preponderance of these lesions, and they appear to be more common on the left side of the subglottis and most often occur posteriorly.⁹ Hemangiomas can be extensive, involving the entire circumference of the airway, or they may extend into glottic, esophageal, thoracic, or cervical tissues and be a part of larger cervical hemangiomas. Fifty percent of patients with subglottic hemangiomas have associated facial lesions, and one series found that children with multiple facial hemangiomas had a 63% rate of symptomatic subglottic hemangioma.¹⁰ A particularly strong association has been found between facial hemangiomas in a beard distribution and subglottic hemangioma. If left without intervention, SGH has a 30%-70% mortality rate.^{7,11}

Infants present with SGH within weeks to months of birth, depending on the initiation of the proliferative phase of tumor growth, with 85% of patients presenting by 6 months of age.¹² The hallmark symptom is airway obstruction with stridor that worsens with crying, while the lesion is engorged, and improves with rest. Often, these recurring episodes of stridor are erroneously labeled recurrent croup because they respond well to steroids, but if ignored too long, complete airway obstruction may occur. At endoscopy, the classic appearance of SGH is a smooth, compressible, submucosal swelling ranging in color from pink to blue, depending on the submucosal depth, and with or without a blush with pressure (Figure 1).⁹

Once a child has been diagnosed with a hemangioma, several treatment options are available, depending on the severity of the obstruction and the rate of progression of disease. If a child with a known subglottic hemangioma displays minimal symptoms, then close observation may be employed, but a narrow threshold for intervention must be maintained until the child is older. It has been shown that a vast majority of patients with SGH will need intervention of some sort.¹³

One treatment, which has been very common but may be falling out of favor among surgeons, is high

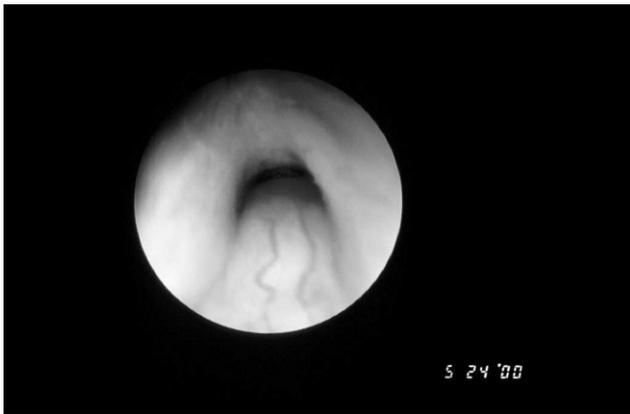


Figure 1. Subglottic hemangioma. Note the smooth, submucosal appearance of this almost completely obstructive mass.



Figure 2. Subglottic hemangioma in Figure 1 several weeks after CO₂ laser therapy.

dose systemic steroid therapy. It is not known how steroids inhibit hemangioma growth, but many theories have arisen, including inhibition of estradiol receptor sites, inhibition of angiogenesis, and increased sensitivity to vasoconstriction.^{14–16} The therapy is often successful, but due to the high dose and length of treatment necessary (prednisone, 4–8 mg/kg/day for 8–12 weeks) and the likelihood of regrowth after cessation of therapy, some physicians believe that the predictable side effects of this treatment are not preferable to surgical intervention. For example, one study found that only 11% of their patients treated with steroids did not require another type of intervention.⁹ On the other hand, another group reported a 90% success rate with systemic steroid therapy alone with minimal side effects.¹⁷ Intralesional steroid therapy has also been used with success, the mechanism of which is also unknown.¹⁸

In 1980, carbon dioxide (CO₂) laser excision came to the forefront of surgical therapy for SGH^{19,20} and has continued to maintain high popularity because it is well-tolerated, effective, and permits treatment without tracheotomy and steroids (Figure 2). Studies over the years have shown high effectiveness with 1 to 3 treatments for the hemangioma and a low rate of tracheotomy.^{19–21} The procedure is not without risks, particularly if overexuberant excision is performed. The excision of an extensive or circumferential SGH requires staged procedures in order to prevent the formation of a circumferential or cicatricial scar, which would result in an iatrogenic subglottic stenosis.²² Post-operatively, patients require respiratory humidification to prevent crusting and improve healing, and a repeat endoscopy for evaluation and possible further treatment may be recommended. Another complication of laser excision includes compromise of laryngeal cartilages and chondritis of the larynx and trachea. Low

intensity potassium-titanyl-phosphate laser is also used for the same purposes and may have an advantage in that it can be transmitted fiberoptically.²³

Another alternative for hemangioma treatment is interferon- α administered subcutaneously. More than 90% of hemangiomas respond with at least a 50% decrease in size to interferon therapy at 3 million U/m² body surface area over 8 to 12 months of daily treatment. However, because of uncommon but potentially severe side effects, this treatment is often reserved for hemangiomas that have not responded to other therapies or for use with extensive cervical, nonsurgical hemangiomas.¹⁰ Side effects include, but are not limited to, fevers, flu-like symptoms, leukopenia, skin necrosis, Lupus-like syndrome, rash, alopecia, spastic diplegia, and aplastic anemia. Most series noted, however, that side effects reversed with cessation of interferon therapy.

Finally, open excision is an option for SGH. There are airway resection techniques and submucosal resection techniques that may be instituted, but these require careful selection of patients for limited lesions since an extensive hemangioma could result in extensive bleeding. When properly selected, these procedures are safe and successful in eliminating SGH without the side effects of medications but with the inherent risks of open airway surgery, such as subglottic stenosis.^{24,25} Biopsy of a suspected SGH is not necessary and may be risky, although it has been shown to be safe in some series.²⁶ Biopsy should be reserved for patients in whom treatment failure or abnormal lesion behavior requires positive histologic confirmation.

Multiple modalities, from medical to surgical, are available to physicians for the treatment of SGH. Treatment must be individualized and the utmost care taken to preserve the natural airway whenever possible. A surgical airway may be required, but even

so, nearly all SGH patients receiving tracheotomy can be decannulated with further treatment.

SUBGLOTTIC STENOSIS (SGS)

With the introduction in the mid-1960's of prolonged intubation for respiratory treatment of premature neonates,²⁷ subglottic stenosis, a previously rare condition, became much more common. This phenomenon coincides with ever-improving survival rates in increasing numbers of premature children. SGS is divided into congenital and acquired variants, and many times these lesions are concurrent since a congenitally narrowed subglottis is at greater risk for intubation injury.

Congenital SGS results from failed or incomplete recanalization of the airway during embryonic development. Cases are further classified into membranous and cartilaginous SGS. Membranous lesions can be thin or thick and may involve the true vocal cords, causing movement restriction, or they may be associated with a laryngeal web. Cartilaginous lesions result from malformed cricoid rings and come in many varieties: Small cricoid ring, in which the cricoid is normal in shape but small (Figure 3); anterior or posterior shelves, where the cricoid has an anterior or posterior malformation; lateral shelves, in which both lateral lamina of the cricoid are malformed, resulting in an elliptical shape; thickened cricoid ring; and a trapped first tracheal ring, in which failure of descent of the first tracheal ring leaves it lining the inner surface of the cricoid cartilage.²⁸

Acquired SGS has been linked to injuries from multiple sources, and it is widely considered to have a multifactorial etiology. The rise in acquired SGS coincides directly with prolonged intubation, as well as with multiple intubations. In addition, associations have been shown between acquired SGS and reflux, surgical and traumatic injuries to the airway, eosinophilic esophagitis, inflammatory diseases (i.e., Wegener's Granulomatosis), and bacterial laryngotracheitis.²⁹⁻³²

Risk factors for SGS include any of the above listed contributing factors, as well as multiple hospitalizations, repeated intubations, prior congenital SGS (up to 8% of acquired SGS), prior tracheotomy, and a history of neonatal neurologic or pulmonary disease. In addition, there is a strong association between multiple craniofacial syndromes and SGS. Patients with Down's, Cri-du-chat, Pfeiffer, Velocardiofacial, CHARGE, and VATER/VACTERYL syndromes all have a predisposition for congenital SGS, as well as for neurologic or respiratory disorders. These patients also typically need other surgical interventions, which results in higher proportions of acquired SGS.³³

The most important factor in dealing with SGS is to prevent the occurrence of SGS altogether. Limiting

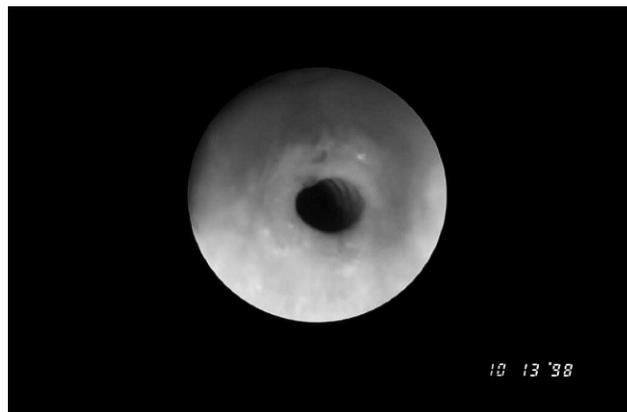


Figure 3. Cartilaginous congenital subglottic stenosis. The cricoid ring is regularly shaped, but small. Note the normal sized tracheal rings distal to the cricoid cartilage.

the duration of intubation is ideal; however, premature infants often require several weeks of intubation for their lung disease to resolve, and prolonged intubation is unavoidable. The use of appropriately sized endotracheal tubes is of utmost importance. Ensuring an air leak below 25 cm H₂O air pressure is generally appropriate for intubation.³⁴ Avoiding repeated intubations/self-extubations as much as possible is also an important step in preventing SGS. Aggressive control of reflux disease and evaluations for esophagitis as required are important adjunctive preventative measures. The surgical treatment of patients with SGS can be fraught with disastrous complications, and all aspects of patient care should be optimized prior to embarking on airway surgery. Hence, it is crucial to address the cardiopulmonary status in these patients and ensure that respiratory disease will not be an issue after surgery so that airway surgery may be performed only once, with or without minor revision.

The evaluation of these patients begins with a thorough history of the reason for intubation and the need for an interventional airway. SGS tends to present while the patient is in the hospital or when the patient has a known airway injury. Often, these patients have been intubated since birth and have failed prior extubation attempts. Sometimes these patients have tracheotomies, and sometimes they present with intermittent stridor or airway distress, depending on the severity of the airway compromise. A history of a syndromic condition or the need for a smaller than expected endotracheal tube, as determined by the intubating physician, are important clues in the history of SGS.

Rigid endoscopy has already been described. But in SGS, careful attention is paid to the variable character of stenoses. These can be composed of a thin membrane, cartilage, soft granulation tissue, or

Table 2. Myer-Cotton Grading Scale

Grade	Percent Obstruction
Grade I	<50%
Grade II	51%–70%
Grade III	71%–99%
Grade IV	100%

firm scar tissue and can be anterior, posterior, or circumferential. Endoscopy also yields information about the dimensions of the patent airway as well as the length of stenotic airway involved. Stenosis is graded by the Myer-Cotton grading scale shown in Table 2. According to this scale, patients with Grade I and II stenosis usually do not require surgery and may be observed with the expectation of growing a larger adequate airway with age. Meanwhile, those with Grade III and IV stenoses almost uniformly require airway surgery for decannulation (Figures 4 and 5).³⁵

Surgical intervention for SGS may be performed at the time of initial endoscopy. Granulation tissue may be removed endoscopically, either with cup forceps or with a CO₂ laser. Membranous or thin (<1 cm) stenoses may be incised with a laser in 4 quadrants and dilated endoscopically at this time as well.^{36,37} Balloon dilation has recently been shown to be a safe and effective method of establishing an adequate airway, without cricoid split, in certain neonates failing extubation.³⁸ Additionally, endoscopic posterior cricoid split, with placement of a posterior rib cartilage graft for spacing, has been advocated for posterior SGS.³⁹

The use of topical mitomycin C has gained popularity over the last several years based on limited evidence that it inhibits scar and granulation formation.⁴⁰ The effectiveness of mitomycin C is disputed, however, and definitive evidence for its efficacy is lacking. In fact, multiple studies have shown little to



Figure 4. This figure shows a Grade III stenosis of about 95%.



Figure 5. This is an example of a Grade I stenosis of about 30%.

no effect in animal models of subglottic injury.⁴¹ Supporters argue, however, that studies suggest that mitomycin is effective at the time of initial injury but is of minimal value during secondary trauma, such as in endoscopic laser surgery. Regardless, mitomycin C is commonly used as a topical agent following endoscopic procedures for subglottic lesions.

Once the lesion has been evaluated and it has been determined that an endoscopic procedure is not an adequate option, a variety of open surgical procedures may be considered, depending on the clinical scenario. These include the anterior cricoid split, laryngotracheoplasty, and cricotracheal resection.

The anterior cricoid split procedure was originally developed for neonates that could not be extubated from a prolonged intubation, with stenosis limited to the subglottis. By performing a decompression of this part of the airway, a tracheotomy is avoided in the neonate.⁴² In this procedure, the airway is exposed after horizontal skin incision. The airway is then incised from the 2nd tracheal ring up through the cricoid cartilage and its coinciding stenosis, and through the lower two-thirds of the thyroid cartilage just below the anterior commissure to reduce the risk of affecting the voice. Once incised, the airway springs open and is stented with the endotracheal tube. The skin is closed over a drain. (This refers to closing the skin with a piece of soft tubing that allows fluid to drain out from the surgical incision while the skin flap heals. The patient is then extubated after 7–10 days.⁴³ If any post-decannulation airway issues occur, patients should undergo repeat endoscopy to evaluate the surgical site.

In laryngotracheoplasty, the anterior cricoid split is performed, and an expanding cartilage graft is placed within the incision to maintain the expansion of the cricoid ring and to provide more expansion than incision alone. Cartilage grafts are most frequently



Figure 6. Carved costal cartilage ready for placement into the airway.

harvested from the costal cartilage and carved with outer flanges that can be used to prevent dislodgement into the airway (Figure 6). The graft is sutured in place with the perichondrium placed interiorly to integrate into the new epithelium (Figure 7). This anterior graft relieves an anterior stenosis. If the patient is diagnosed as having a posterior stenosis or severe stenosis not relieved by anterior grafting alone, a posterior cricoid split may be required as well. Once the posterior lamina of the cricoid is incised, a cartilage graft is inserted as an expander and is sutured in place, similarly to the anterior cartilage. The airway is immediately evaluated for expansion prior to transferring the patient from the surgical suite. Laryngotracheoplasty can frequently be performed in a single-stage procedure using an

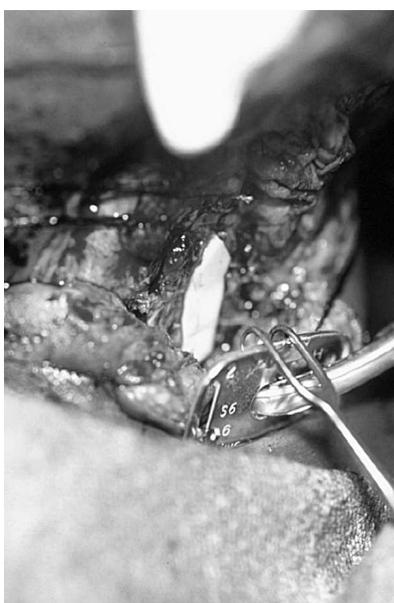


Figure 7. Costal cartilage graft in place in the reconstructed airway.



Figure 8. Endoscopic views of a subglottic stenosis prior to expansion with an anterior laryngotracheoplasty.

endotracheal tube as a stent to hold the cartilage grafts in place during 7–10 days of healing (Figures 8 and 9).^{44,45} If a patient enters the procedure with a tracheotomy, the tracheotomy may be incorporated into the anterior airway incision and closed using the cartilage graft. Other surgeons prefer to complete these procedures with a tracheotomy intact, and they place a stent in the surgical site with plans to return to the operating room for removal of the stent 2–6 weeks later, after airway reevaluation. This allows for minor revisions as well, such as removal of granulation tissue, which sometimes occurs with stents. Complications of this procedure include restenosis, granulation formation, graft failure or dislodgement, and poor voice due to overexpansion of the anterior commissure of the glottis.

Severe subglottic stenoses, such as severe grade III and all grade IV, may require a more extensive surgery called cricotracheal resection (CTR). In this procedure, the anterior two-thirds of the cricoid cartilage is resected along with the full extent of the

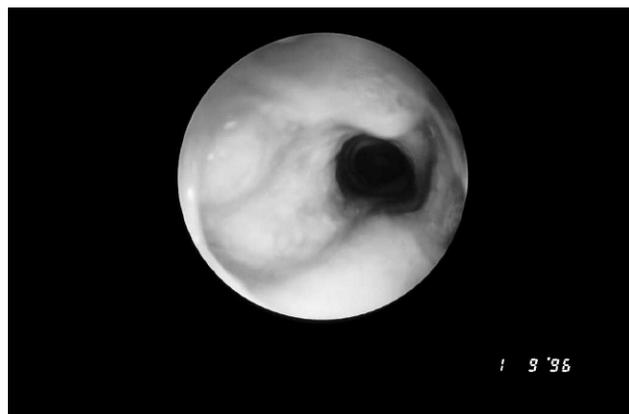


Figure 9. This is the same patient from Figure 8 after anterior LTP. Note how well the perichondrium incorporated into the new mucosa of the newly expanded airway.

stenotic segment of airway. The upper trachea is then mobilized from the esophagus posteriorly, and further mobilization procedures may be performed superiorly and inferiorly to release tension on the airway anastomosis. These maneuvers include release of peritracheal tissues inferiorly and a suprahyoid release superiorly to allow descent of the larynx. The proximal tracheal end is then reanastomosed to the inferior thyroid cartilage. It should be noted that the posterior cricoid lamina is left intact in order to contribute some structural support to the reconstructed airway, as well as to protect the recurrent laryngeal nerves which lie in the tracheoesophageal groove posteriorly. Damage to these nerves is one of the primary risks of the procedure, along with anastomotic dehiscence, which can be a catastrophic complication, pneumothorax, and restenosis at the anastomotic site. CTR may also be used after failed laryngotracheoplasty or restenosis, and CTR does not preclude the use of laryngotracheoplasty in the face of restenosis. CTR has also been shown to be safe and effective in very small children.^{46,47}

After any of the above airway procedures, endoscopy 4–6 weeks after surgery may be performed to evaluate the postoperative airway, to ensure patency and address any minor revisions that are required, such as granulation removal, or to identify a restenosis. After a single-stage procedure, some surgeons prefer to extubate the patient in the operating room to evaluate the airway at that time. Patients will often need no further postoperative endoscopic evaluation, however, if they are symptom-free. Patients that still have tracheotomies may be downsized and gradually decannulated with subsequent follow-up appointments. Overall, decannulation rates exceed 90% within one year of airway surgery and 95% overall.⁴⁸

GRAFTS AND STENTS

Costal cartilage is the workhorse cartilage for airway reconstruction because it can be sculpted into varying thicknesses, is durable and strong, and has proven to incorporate well in the airway. The graft is harvested from the 5th or 6th rib cartilage, where the incision can be placed so it will incorporate into the future breast line in girls. The costal cartilage is thick enough that adequate cartilage may be left in place to prevent injury to the pleura, which would result in a pneumothorax. However, should this occur, the lungs may be reinflated with positive pressure and the hole closed with a purse-string suture.

Other grafts that may be used include the thyroid cartilage graft and the auricular cartilage graft. Auricular cartilage use is generally discouraged because of the potential for auricular deformity and because the cartilage is so thin that its usefulness is



Figure 10. A stent attached to a metal tracheostomy tube. The white portion is not hollow superiorly and the top protrudes slightly through the vocal cords.

limited. Thyroid cartilage grafts are most frequently used for cap grafting over anterior cricoid split procedures and for laryngotracheoplasty.⁴⁹

Stents are used to maintain patency of the airway during healing and to help hold cartilage grafts in place as they heal. They also prevent dislodgement of the grafts into the airway, which will result in a foreign body in the airway (Figure 10). Single-stage procedures are performed more and more frequently, utilizing the endotracheal tube as a short-term stent. When a stent is needed for a longer period, a multitude of stents are available, the most common of which is a Montgomery T-tube. Many stents have a closed end that protrudes through the vocal cords superiorly and an open end inferiorly attached to an open end that protrudes through a tracheotomy. These stents require meticulous care as they are predisposed to crusting, and they require a second procedure for removal and evaluation of the airway. The stents are predisposed to granulation formation, and the 2nd stage procedure often involves removal of granulation. Because the upper end of the stent protrudes through the glottis, it also causes a certain amount of aspiration, which must be monitored. These stents, however, may be left in place for several weeks to months, allowing long-term healing and treatment of other factors prior to decannulation.⁵⁰

CONCLUSION

Obstructive lesions of the pediatric subglottis present a challenging problem to treating physicians. It is most important to maintain and preserve the airway at all times, with the eventual goal of obstruction relief. Accurate diagnosis and timely response to each patient's individualized needs are critical, and early decannulation of the child with minimal effect to speech development remains the

goal of reconstructive airway surgery. With adequate care, nearly all patients' diseases can be adequately addressed in a methodical, safe manner.

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