Endoscopic Management of Laryngotracheal Disease

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KEYWORDS

• Benign airway strictures • Subglottic stenosis • Tracheal stenosis • Endoscopic

KEY POINTS

- Endoscopic techniques are first-line options in the management of benign laryngotracheal stenoses. Open procedures may be considered where serial endoscopic techniques have failed.
- Absolute contraindications to endoscopic management include luminal narrowing due to external compression or significant cartilaginous framework collapse.
- Pharmacologic adjuncts, such as inhaled or injected corticosteroids, topical mitomycin C, and oral antibiotics, may prolong the effects of surgical intervention.
- Spirometry is a cost-effective, accessible tool for monitoring the presence of an upper airway obstruction and may assist in determining the optimal time for repeat procedures.
- Benign adult airway stenoses often overlap the glottic–subglottic–tracheal boundaries and require a combined multidisciplinary approach to management.

INTRODUCTION

Laryngotracheal stenosis (LTS) encompasses a heterogeneous spectrum of conditions characterized by the luminal narrowing of the supraglottis, glottis, subglottis, or trachea.[1] Endoscopic interventions are considered to be first-line treatment options but carry a higher rate of recurrence compared to open techniques.[2] Consequently, the number of endoscopic modalities continues to expand without a clear consensus on the most appropriate treatment choice. Today, commonly used techniques include balloon or rigid dilation, laryngeal microsurgery, laser-assisted excision, and endoscopic stent placement (for complex, recurrent, and inoperable cases) in conjunction with pharmaceutical adjuvants. The purpose of this article is to review these options along with their functional outcomes.

EVALUATION

The initial evaluation of suspected airway stricture requires a thorough historical and physical examination followed by a dynamic airway assessment to characterize the depth, longitudinal involvement, and maturity of the stenosis. This assessment may be performed in the office under local anesthesia in select patients. However, it is better tolerated in a bronchoscopy suite or operative setting with moderate sedation. A comprehensive review of the patient's symptoms and past medical/surgical history is crucial to determine the ideal therapeutic approach. LTS commonly presents with dyspnea; other symptoms including dysphonia, tachypnea, aspiration, and dysphagia may also occur depending on the level of stenosis. Risk factors for iatrogenic LTS include the number and duration of prior endotracheal intubations,

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Thorac Surg Clin 35 (2025) 25–36
https://doi.org/10.1016/j.thorsurg.2024.09.003
1547-4127/25/

prior airway surgeries, diabetes mellitus, reflux, obesity, obstructive sleep apnea, radiation exposure, blunt or penetrating cervicofacial trauma, tobacco or alcohol use disorder, and chemical or thermal injuries.[3] In cases with no obvious traumatic or iatrogenic cause, a possible inflammatory/autoimmune or neoplastic condition should be investigated. Initial steps include a serum antineutrophil cytoplasmic antibody (c-ANCA), autoimmune profile, angiotensin-converting enzyme (ACE) level, serum testing, culture, and biopsy of the involved tissue, and a rheumatology referral. Though relatively rare, infectious sources must also be considered, particularly if there is concern for exposure to tuberculosis (**Box 1**).

Observation of audible breath sounds is the manifestation of rapid, turbulent airflow through a partially obstructed airway. On physical examination, attention to respiratory pattern, and an understanding of the phase of obstruction may provide initial information about the severity and level of narrowing. Stridor and stertor typically affect the inspiratory phase and may present in the setting of extrathoracic upper airway obstruction. The key distinction between the 2 findings is the distinct difference in pitch. Stridor is a high-pitched, voiced or fricative sound associated with substantial narrowing of the larynx or extrathoracic trachea. Inspiratory and expiratory stridors are indicative of obstructions above the glottis and within the upper trachea, respectively. Biphasic stridor is a concerning finding suggestive of a severe, fixed lesion typically at the level of the immediate subglottis or glottis. The combination of biphasic stridor with increased work of breathing is an ominous sign of impending respiratory failure, which may require urgent intervention. Alternatively, stertor is a low-pitched, wet sound akin to snoring. It is the result of bidirectional tissue vibration within the nasopharynx, oropharynx, and hypopharynx. Intrathoracic obstruction may present with expiratory wheezing due to obstruction or cartilaginous collapse upon air escape. The intensity, pitch, and duration of wheezing is thought to be correlated with severity of obstruction.

Box 1
Common causes of laryngotracheal stenosis

Supraglottic stenosis

- Autoimmune: Amylodosis, IgG4-related, sarcoidosis, systemic lupus erythematous, granulomatosis with polyangiitis, cicatricial pemphigoid
- Iatrogenic: External-beam radiation,
- Traumatic: External trauma to the thyroid cartilage notch
- Thermal/chemical injury

Glottic stenosis

- Thermal/chemical injury: Oversized endotracheal tube chemical inhalation, thermal injury, caustic ingestion
- Iatrogenic: Radiation, prior airway surgeries
- Infectious: Syphilis, croup, diphtheria, fungus
- Bilateral vocal fold paralysis

Subglottic stenosis

- Idiopathic
- Iatrogenic: Endotracheal tube cuff pressure, tracheostomy, radiation, prior airway surgeries
- Infectious: Bacterial tracheitis, tuberculosis, recurrent respiratory papillomatosis
- Traumatic: Blunt cervical injury, penetrating cervical injury
- Autoimmune: Granulomatosis with polyangiitis (GPA), relapsing polychondritis, rheumatoid arthritis (RA), amyloidosis

Office-based laryngoscopy should be used to evaluate most patients with a suspected extrathoracic obstruction and include flexible fiberoptic laryngoscopy to evaluate the extent of potential stenoses as well as vocal fold and cricoarytenoid joint mobility. Preoperative imaging, such as a multiplanar computed tomography scan of the neck and chest, should be considered in all LTS cases. If a mass effect from a goiter or a large mediastinal lesion is suspected, contrast-enhanced computed tomography is indicated. For lesions involving the trachea, flexible and dynamic bronchoscopy is needed to assess the extent and degree of narrowing and detect underlying cartilaginous collapse. A concurrent esophagoscopy may also be indicated if there is suspicion of a neoplastic process.

Performing spirometry on these patients may help to establish a baseline for monitoring their status over time but should be avoided in the setting of acute, symptomatic airway obstruction.

Classification and Etiology

The diagnostic standard of care for LTS is an examination under anesthesia with flexible bronchoscopy to characterize the anatomic characteristics (eg, number, length, and extent of subsites involved, immature or fibroinflammatory activity vs mature, cicatricial scarring, overall length, distance from the glottis, and distance from main carina). These are relevant as complex stenoses recur at high rates (60%–80%) post dilation, and long stenoses (>5 cm) may not be amenable to open surgical resection. It is also important to assess the mobility of the cricoarytenoid joint to differentiate posterior glottic stenosis (PGS) from bilateral vocal fold paralysis. This can be done by performing a direct laryngoscopy with direct palpation of the arytenoids to determine the degree of mobility of each cricoarytenoid joint. Several classification systems have been designed to risk stratify stenosis morphology to the likelihood of future decannulation. The 3 most used are detailed in **Table 1**, though the McCaffrey and Lano systems are more applicable to the adult airway.

SUPRAGLOTTIC STENOSIS

Benign supraglottic stenosis is exceedingly rare, comprising only 3% to 4% of reported LTS cases. Causative factors include prior head and neck radiation (46%), autoimmune (23%), or iatrogenic injury (15%).[4,5] Surgical treatment of benign supraglottic disease should be approached on a case-by-case basis because of the high risk of recurrence or exacerbation after endoscopic intervention. A case series, Vira and colleagues included 4 patients with recurrent supraglottic stenosis requiring serial dilations. The study found that the combination of balloon dilation and CO_2 radial incisions afforded a 12-month treatment-free interval (TFI) compared to the 6-8-week interval granted by balloon dilation alone before intervention. Anecdotally, topical mitomycin C (MMC) at a concentration of 0.4 mg/mL with a 4-min application had an added increase in TFI.[4] Another group published their experience with an endoscopic Z-plasty technique in 9 patients with supraglottis stenosis, after which all patients were decannulated 1 month after surgery. However, this technique may be difficult to apply broadly.[6]

ACUTE POST-INTUBATION LARYNGEAL INJURY

Acute intubation-related trauma is caused by direct insertion-related trauma or pressure-induced mucosal injury of the upper airway by an indwelling endotracheal tube. Acute fibroinflammatory changes, characterized by mucosal ulceration or granulation tissue are visible within the first days to weeks of the inciting incident. There is a direct correlation between the depth of ulceration, the quantity of early granulation tissue, and the severity of future airway stenosis, the rate of which sharply increases after a duration of intubation greater than 7 to 10 days.[7–9] Furthermore, untreated perichondritis of the arytenoid cartilage may lead to cricoarytenoid joint fibrosis and high-grade PGS at diagnosis. The 3 areas most vulnerable to intubation-related injury in the average adult are the medial surfaces of the vocal process, the intra-arytenoid region, and the posterior subglottis along the inferior aspect of the cricoid cartilage. PGS is associated with the compromise of the thin mucosa overlying the arytenoid cartilages by the caudal turn of the endotracheal tube through the glottis. Subglottic and tracheal stenoses are associated with injury from the tube's balloon or distal tip. Factors such as size, elevated cuff pressure, local infection, prone positioning, chronic disease states (eg, diabetes, autoimmune conditions, vascular disease, and obesity), uncontrolled

Table 1
Common grading nomenclature for laryngotracheal stenosis

Classification System	Stage	Criteria	Decannulation
McCaffrey	I	Lesions are confined to the subglottis or trachea and are < 1 cm long	90%
	II	Lesions are isolated to the subglottis and > 1 cm long	
	III	Subglottic/tracheal lesions not involving the glottis	70%
	IV	Lesions involve the glottis	40%
Cotton-Meyer	I	Up to 50% subglottic obstruction	
	II	51%–70% subglottic obstruction	
	III	71% to 99% subglottic obstruction	
	IV	100% subglottic obstruction	
Lano-Netterville[a]	I	One subsite involved	94%
	II	Two subsites involved	78%
	III	Three subsites involved	20%

[a] Subsites: subglottis, glottis, subglottis, trachea.

laryngopharyngeal reflux, and frequent tube adjustments, compound this risk.

In studies investigating the benefit of early endoscopic treatment of intubation-related injuries, a regimen of intralesional corticosteroid injection, granulation tissue removal, and balloon dilation resulted in fewer total future interventions and a greater treatment-free interval.[10] For PGS treated within 45 days of injury, the above endoscopic therapy resulted in decreased time to decannulation, increased rates of decannulation, and complete avoidance of open reconstruction. Additionally, as more information emerges about the mucosal microbiome, both postintubation antibiotic coverage and inhaled steroid prophylaxis have been advocated to avoid prolonged sequelae associated with acute postintubation laryngeal injury.[11] Unfortunately, it is rare for patients to present within the early phase of wound healing as postintubation injuries often have delayed onset of subjective dyspnea, only presenting 4 to 12 weeks after the inciting incident.[10] This, however, highlights the importance of vigilance as it relates to patients who are at risk for acute laryngeal injury including those patients with a shorter stature, higher body mass index, and those who are intubated with a larger endotracheal tube.

ANTERIOR GLOTTIC STENOSIS

Surgical treatment of glottic stenosis often requires serial interventions and improvement is variable. Operative indications include airway restriction and symptomatic dysphonia, and relative contraindications include uncontrolled laryngopharyngeal reflux or absent symptoms. Release of anterior glottic webs can be performed with either up-going scissors versus a sickle knife or with a CO_2 laser but carries a significant risk of recurrence if performed alone. Therefore, it is advised that scar lysis be performed in combination with mucosal grafting or airway stenting with a silastic keel.[3,12] Cold instrumentation is typically preferred to minimize the theoretic risk of heat-induced scar formation; however, few reports indicate a clear benefit over the cold knife with the availability of super-pulse or maximal cutting mode to reduce char.

Anterior Glottic Web Release with Endoscopic Mucosal Flap Grafting or Endoscopic Keel Placement

A mucosal flap approach is best suited to smaller membranous vocal fold defects. Cuts are made asymmetrically to optimize the size of the potential mucosal flap then folded over the ipsilateral area of the devitalized anterior commissure and sutured to the inferior surface of the true vocal fold (TVF).[13] Various grafts have been used to cover the raw area, such as skin grafts, endonasal or buccal mucosa, and perichondrium-cutaneous composite grafts, however, none of these options have properties that would be needed to produce a voice with good fidelity. Endoscopic buccal mucosal grafting (EBMG) is a newer reconstructive technique that can be used primarily or at the time of secondary reconstruction, however, this must be considered as a last option given the potential difference in pliability that exists for buccal mucosa compared to the thin epithelium and superficial lamina propria. Contraindications to mucosal grafting include inadequate exposure, cartilaginous stenosis involving the anterior larynx, and coverage after resection of a malignant lesion with a high risk of recurrence. Relative contraindications for any mucosal flap grafting include prior radiation therapy, poorly controlled diabetes, immunosuppression, or a history of poor wound healing. For large defects without enough mucosa to adequately cover raw surfaces, a stent or a keel can be considered. Today, silicone is the material of choice, as it is flexible and easy to cut to the size and shape of individual airways. In a systematic review comparing mucosal flap suturing with and without keel placement, the pooled, complete resolution rates were 84% and 77%, respectively.[12]

Postoperative Care and Complications

Postoperative care for endoscopic anterior web release includes perioperative intravenous antibiotics and steroids. Patients should be kept for overnight observation, and a course of oral antibiotics with reflux prophylaxis should be considered. Minor complications include an overly bulky graft and blunting of the anterior commissure. Major complications include anterior glottic web reformation, premature stent extrusion or keel displacement due to severe cough or suture rupture, graft failure, and granuloma formation at the stay sutures.[14] Following anterior commissure, keels and silastic stents for EBMG are typically removed under general anesthesia after 10 to 14 days.

POSTERIOR GLOTTIC STENOSIS

The Bogdasarian and Olson Classification provides a scheme for distinguishing PGS based on the severity of stenosis (Table 2).[9,15] In this schema, low-grade (Type I-II) and high-grade PGS (III-IV) are sharply differentiated by fixation of at least one cricoarytenoid joint. High-grade

Table 2
Bogdasarian & Olson classification system for posterior glottic stenosis (PGS)

Type	Features
Type 1	Interarytenoid scar bad which does not extend to the posterior commissure.
Type 2	Interarytenoids scar band extending to involve the entire posterior commissure
Type 3	Posterior commissure scar with involvement of one cricoarytenoid joint, typically with unilateral immobility of vocal fold.
Type 4	Posterior commissure scar involving both cricoarytenoid joints with bilateral immobility of vocal folds.

PGS can be distinguished from bilateral vocal fold paralysis with palpation of the cricoarytenoid joint under direct laryngoscopy. Alternatively, laryngeal electromyography may demonstrate normal activity of the thyroarytenoid–lateral cricoarytenoid versus an absent or partial response in bilateral vocal fold paralysis(BVFP), although partial or selective paresis has been theorized.

Surgical indications for PGS include airway obstruction and the possibility of tracheostomy decannulation. Relative contraindications include poor pulmonary reserve, prior radiation therapy, uncontrolled laryngopharyngeal reflux, and tracheostomy dependence required by other conditions (obesity hypoventilation syndrome, severe obstructive sleep apnea (OSA), neurologic etiologies). Although glottic enlargement strategies apply to both PGS and BFVP, the distinction must be made to reinforce realistic patient expectations regarding achievable voice quality and respiratory status. Often, the causative injury results in cartilaginous disruption with loss of normal arytenoid structure or fusion of the arytenoid to the cricoid ring. This predisposes the patient to a cycle of recurrent scar formation and thus requires aggressive techniques to achieve airway patency with the sacrifice of voice quality.[16] Ablative procedures such as posterior transverse cordotomy or partial arytenoidectomy may be used in moderate PGS but may be less successful owing to the risk of erosion of the posterior cartilaginous glottis and subsequent re-scarring.[14] Other techniques include CA joint mobilization with lateropexy, subtotal arytenoidectomy with permanent suture lateralization, and endoscopic posterior cricoid split with costochondral cartilage grafting with a concurrent tracheotomy.

Lysis of Interarytenoid Synechiae

Isolated interarytenoid synechiae (Type 1 PGS) may respond favorably to scar excision and balloon dilatation alone with or without corticosteroid injection. In a series of 13 patients undergoing CO_2 laser excision for a Type 1 PGS, 83% and 54%, respectively, reported tracheostomy decannulation and subjective return to preintubation vocal function, and no participants experienced changes in their swallowing function.[17] However, it is unclear how lasting these benefits are, as the length of postoperative follow-up was not reported. For Types II-IV PGS with failure to reestablish CA joint mobility, the next options are transverse cordotomy or medial arytenoidectomy.[3]

Endoscopic Modified Postcricoid Advancement Flap (EPAF)

Goldberg introduced the concept of the endoscopic postcricoid advancement flap for the treatment of moderate to severe PGS.[18] In this procedure, a vascularized mucosal flap on the posterior surface of the larynx is elevated followed by endoscopic scar excision with a CO_2 laser and eventual suturing of the flap to the interarytenoid region.[18] Candidates for this procedure must have at least one mobile arytenoid so that a larynx with adequate abduction can result.[18] The original EPAF has since been modified to use a subglottic “trap door” flap for greater ease of suture placement and postcricoid flap inset and remains appropriate for PGS Types II and above.[18,19]

Endoscopic Arytenoid Abduction Lateropexy

Endoscopic arytenoid abduction lateropexy following scar ablation is best suited for PGS Type III-IV.[20] Rovo and colleagues, reported that 87.5% of recipients achieved subjectively improved ease of respiration, and 96.9% were successfully decannulated.[20] Furthermore, once reepithelialization of the posterior commissure is confirmed, the lateralizing sutures are removed. Phonation typically improves over the next several weeks. Botox injections into the interarytenoid and thyroarytenoid muscles may also be used in the postoperative period. The botulinum toxin results in a temporary paresis of the adductor muscles, preventing overadduction in the posterior commissure and attenuating the risk of restenosis.

BILATERAL VOCAL FOLD PARALYSIS

Bilateral vocal fold paralysis is a rare but serious condition caused by reduced or absent innervation to the intrinsic laryngeal musculature. The most common etiologies include iatrogenic insult and mass effect that may disrupt the vagus nerve anywhere along its course from the jugular foramen through the recurrent laryngeal nerve (Box 2). Following, patients may present with severe inspiratory dyspnea due to fixed narrowing of the glottic inlet or progressive synkinesis due to aberrant reinnervation. Surgical interventions largely focus on balancing maximal relief of symptomatic airway obstruction while preserving the protective airway mechanisms involving the arytenoids. Contraindications to endoscopic techniques include poor pulmonary reserve, prior head and neck radiation therapy, and fluctuating neurologic disorders (eg, multiple sclerosis). For the latter, a tracheostomy may be the most appropriate option to ensure consistent airway protection. One of the most important considerations in surgical planning is the presence of a purposeful vocal fold mobility. The side with the least spontaneous movement or least mobile cricoarytenoid joint is typically selected for intervention. Within the first 9 to 12 months of injury, nonablative measures such as suture lateralization or botulinum toxin can be used to temporarily bypass the obstruction while the damaged nerve regenerates. After this period, ablative glottic enlargement techniques, including posterior transverse cordotomy, medial arytenoidectomy, or total arytenoidectomy, can be performed in a step-wise manner. In persistently recalcitrant cases, open procedures should be considered.

Box 2
Common causes of bilateral vocal fold paralysis

Processes that physically compromise both nerves:

- Latrogenic:
  1. Total thyroidectomy
  2. Bilateral carotid endarterectomy
  3. Skull base/brainstem surgery
- Compressive:
  - Of bilateral recurrent laryngeal nerves:
    1. large thyroid mass
    2. Paratracheal lymphadenopathy
    3. Massive mediastinal lymphadenopathy
    4. Clothesline injury to the neck
  - Of bilateral vagus nerves:
    1. Brainstem tumor
    2. Massive bilateral cervical lymphadenopathy

Systemic neurologic conditions:

1. Shy-Drager (Multiple system atrophy)
2. Bradbury-Eggleston syndrome (Idiopathic orthotatic hypotension)
3. Arnold-chiari malformation (Congenital cases)
4. Hydrocephalus (Congenital cases)

SUBGLOTTIC AND TRACHEAL STENOSIS

Subglottic stenosis (SGS) and tracheal stenosis encompass symptomatic airway narrowing below the level of the glottis. Approximately 25% of the cases are attributed to iatrogenic injury, particularly in the setting of endotracheal intubation and tracheostomy placement.[21] Other etiologies include autoimmune conditions such as infection (TB, RRP, and bacterial) and inhalation injury.[21] In 33%, the absence of any preceding injury is termed as idiopathic SGS (iSGS).[21] Adult airway stenoses often overlap the subglottic-tracheal boundary, allowing for multiple shared treatment options and decision-making.

The primary endoscopic surgical indication is cicatricial airway lumen narrowing with dyspnea. Patients with airway narrowing due to mass effect, tracheomalacia, or significant cartilaginous disruption are not candidates for endoscopic treatment alone (short of airway stent insertion). Extensive length of stenosis (greater than 2–3 cm), circumferential morphology (as opposed to eccentric scar), and the presence of chondritis define complex stenoses and are predictors of recurrence after endoscopic management. These patients need either open resection or, if not surgical candidates, airway silicone stenting placed via rigid bronchoscopy. Endoscopic treatment techniques include radial incision or wedge resection using a CO_2 or potassium titanyl phosphate (KTP) laser, precise electrosurgery knife-radial incisions, dilation via rigid or flexible bronchoscopy, suspension laryngoscopy with balloon dilation, or cold knife scar excision. Generally, a combination of these endoscopic techniques is supplemented with MMC or corticosteroid injections.[22] Unless contraindicated, the least invasive procedures are attempted first and can produce durable results, saving more invasive or external procedures for cases that fail to respond to endoscopic approaches. The major shortcoming of endoscopic treatment of SGS/postintubation tracheal stenosis (PITS) is the frequent need for repeated surgery because of restenosis.[23] The main goal of endoscopic treatment is to maintain airway patency to a nonflow limiting degree of narrowing (<50% obstruction) while minimizing mechanical and thermal trauma during the endoscopic procedures (as they could lead to scar tissue recurrence). In our practice, all complex stenoses are presented to a team of laryngologists, thoracic surgeons, and interventional pulmonologists for shared decision-making.[1]

It is noteworthy that posttracheostomy stenoses can occur at 4 sites: suprastomal, stomal (eg, A-frame, lambda-shaped, triangular, pseudoglottic), site of tracheostomy tube cuff, or distal to the tracheostomy tube due to chronic infection, dynamic airway collapse, or misalignment of the tracheostomy tube and tracheal lumen. The classic stomal strictures (A-frame), without cicatricial tissues, do not respond to endoscopic treatment alone because of cartilaginous collapse, and when symptomatic, should be managed by open surgical resection, or in nonsurgical candidates, by silicone stent placement.[1] Though there are reports of successful stent removal after 6 to 18 months, the optimal duration of placement, without the need for further airway interventions, is unknown. In our practice, this is a rare event, likely because we reserve stenting for the most complex, inoperable stenoses, when there is significant cartilage destruction or absence, and remodeling is unlikely.

In treatment-naïve infraglottic stenosis, Carbon dioxide (CO_2) laser excision portends increased rates of recurrence compared to balloon dilation regardless of etiology.[24] The average treatment-free interval with endoscopic dilation alone is 13.7 months.[21] Among the CO_2 laser and balloon dilation groups, 1-year recurrence rates were 63.2% and 12.9%, respectively.[24] After 3 years, the difference remained significant at 73.7% versus 51.6%.[24] There is controversy regarding the ideal strategy to prevent restenosis in previously treated airways. Gelbard and colleagues demonstrated an increased treatment-free interval after partial laser resection in addition to dilation alone.[2] Treatment-naïve, simple tracheal stenoses (<1 cm) can be treated with endoscopic dilation alone or laser- or electrocautery-assisted radial incisions of stenosis plus rigid bronchoscopic dilation. In a study by Gallucci and colleagues, this technique, also known as laser-assisted mechanical dilation, had a 4% recurrence at the 1-year follow-up.[25] In recurrent cases, the authors report that a maximum of 3 endoscopic treatments were attempted before airway stenting or open reconstruction.[25] It is essential to be cautious while performing laser work in the airway to avoid thermal trauma that could lead to recurrence. In the subglottis, this is even more relevant, to avoid harming surrounding structures including the vocal fold epithelium to the risk of scar and subsequent permanent hoarseness. A 5-year study comparing 3 surgical techniques for iSGS found that open cricotracheal resection (CTR) had the lowest repeat intervention rate at 5%, followed by endoscopic resection with adjuvant medical therapy (ERMT) at 30%), and endoscopic dilation at 50%.[26,27] However, recipients of the latter reported the best patient-reported voice outcomes overall, as measured by the Voice Handicap Index-10 (VHI-10).[23] The improved disease control over endoscopic dilation, improved voicing over CTR, and comparable quality-of-life scores suggest that ERMT should be strongly considered in iSGS.

Serial Intralesional Steroid Injections

Circumferential serial intralesional steroid injections (SILSI) with either methylprednisolone acetate (1–2 mL of 10 mg/mL) or triamcinolone (Kenalog, 2 mL of 40 mg/mL) is a consideration to attenuate the rate of restenosis. Injections can be administered either before or after ablation at the time of intervention. However, it is suggested to inject before making radial cuts to improve liquid retention. Recent studies have shown that in-office injections of 3 to 6 doses of triamcinolone 40 mg/mL can be highly beneficial for patients.[12] Injections are spaced 3 to 6 weeks apart. In addition to this, providers may consider a regimen of inhaled corticosteroids for 1 month and oral antibiotics for 2 to 4 weeks. This intervention doubled the surgery-free interval following endoscopic dilation and decreased the rate of overall recurrence.[23,28] Office-based SILSI is well-tolerated in adults with infraglottic LTS and has the potential to obviate the need for future endoscopic interventions.[23] With regards to cost, the average annual charges for patients treated with endoscopic dilation alone was $15,383.28, compared to $7070.04 for endoscopic dilation followed by SILSI.[29]

Mitomycin C

Following mucosal sparing techniques, such as scar excision with a cold knife or CO_2 laser, topical application of MMC has been purported to reduce cicatricial scarring and extend the treatment-free interval with even a single dose of 0.1 to 0.2 mg/mL.[30] In a prospective, randomized cohort study, Smith and colleagues demonstrated that 2 topical applications of MMC at 0.5 mg/mL for 5-min duration resulted in an even greater recurrence-free interval than the single-application group.[31] Published data, however, is mixed as others have suggested that MMC delayed but did not prevent the recurrence of stenosis or has no additional benefit.[21,31,32] Furthermore, there is concern about the local toxicity caused by MMC, particularly with higher concentration doses. Reported complications range from 2% to 4.7%, frequently involving partially obstructing accumulation of fibrinous debris.[31,33] In animal studies, applications of MMC alone at low (0.2 mg/dL) and high (0.5 mg/dL) doses demonstrated no significant changes in stenotic tissue between the placebo and low-dose group. The high-dose group demonstrated a two-fold increase in stenosis compared to the others.

Maddern Procedure

The Maddern procedure is a technique used to treat SGS. It involves the resection of subglottic scarring using a CO_2 laser followed by a buccal graft secured into the subglottis by an external suture. The graft serves as a means of reconstituting healthy mucosa in lieu of fibrotic scar.[34] Though initially described as a transcervical procedure, it has evolved to allow a completely endoscopic intervention. A prospective case series including 26 patients undergoing the transoral endoscopic Maddern procedure has demonstrated success with 72% objectively favorable outcomes and 92% of patients stating that they would elect to undergo the procedure again, without significant complications.

AUTOIMMUNE-MEDIATED LARYNGOTRACHEAL STENOSIS

Infraglottic LTS is the initial manifestation for 66% of patients with airway-involving autoimmune conditions. Granulomatosis with polyangiitis (GPA) and relapsing polychondritis are the most common etiologies of autoimmune-related SGS, and successful treatment of these 2 conditions sets a therapeutic precedent for other forms of autoimmune LTS. Though endoscopic dilation with laser resection is the mainstay of care for 65% of autoimmune LTS, an effective immunosuppressive regimen is crucial to optimize the longevity of postoperative airway patency.[35,36] Autoimmune SGS is a relative contraindication to tracheal resection and reconstruction surgery. Novel immunosuppressive infusions such as Rituximab mitigate the need for multiple surgeries in this patient population. A conservative approach with optimal medical therapy is highly recommended in this patient population given the potential risk of superior creep of the disease and possible involvement of the glottis, which can lead to a more refractory stenosis with concurrent dysphonia.

Granulomatosis with Polyangiitis

GPA affects the airway in approximately 16% to 23% of the patients.[37] GPA-SGS often progresses independently from the disease's overall course and is generally refractory to medical management alone.[36,38] The classic manifestation is circumferential narrowing limited to the subglottis and proximal trachea (85%), of which one-third eventually develop multilevel airway stenosis involving the distal trachea (16%), bronchi (11%), and cricoarytenoid joints resulting in bilateral vocal fold immobility (20%–23%).[35,39,40] It is important to distinguish idiopathic from GPA-related stenosis as the latter has a more aggressive course. These patients are also poor candidates for open surgeries, often requiring further serial dilations or eventual tracheotomy after definitive reconstruction.[41] Of note, serology in airway-limited is often unrevealing, making a comprehensive clinical and laryngoscopic evaluation essential to diagnosing these patients.

The leading surgical intervention for GPA-related stenosis is endoscopic balloon dilation with SILSI or the intratracheal dilation injection technique (IDIT).[23,37,42] IDIT resulted in a lower number of repeat endoscopic procedures and increased treatment-free interval and decannulation rate in treatment-naïve patients. The benefits of IDIT were further amplified for patients undergoing concurrent systemic treatment.[28] In a small series, rituximab was shown to be more effective for treating GPA–SGS relapses while tracheobronchial stenoses responded better to cyclophosphamide induction.[5] However, distal tracheobronchial lesions are typically more amenable to medical therapy alone (75%) compared to GPA–SGS (35%).[38]

Relapsing Polychondritis

Relapsing polychondritis is a multisystem disease characterized by recurrent episodes of cartilaginous inflammation. Cellular and humoral responses against collagen type II, IX, and XI are seen in 30% to 70% of the patients. Auricular chondritis is identified in ~90% of the patients on careful history and physical examination.[43,44] Many patients have a delay in diagnosis for almost 3 years as the disease presents as an asthma imitator.

Airway involvement in relapsing polychondritis is seen in 50% of patients, and it favors the anterior trachea, frequently extends to the bronchi, and demonstrates abnormal calcification and cartilaginous erosion of the upper airway framework. Respiratory symptoms are the initial presentation in 14% of the patients. SGS and tracheobronchomalacia are seen in 26% and 48% of the patients, respectively.[45] Therapy includes immunosuppressives, but once the cartilage is destroyed, patients may eventually require stent insertion or tracheostomy placement because of severe tracheobronchomalacia (Fig. 1). These patients tend to carry high operative risk and should be taken for biopsy and intervention with caution in a multidisciplinary team. The reported 5-year survival rate generally ranges from 66% to 74% but may be as low as 45%.

Fig. 1. A rigid bronchoscopy image of a patient with relapsing polychondritis. Notice the significant circumferential collapse of the airway despite administration of positive pressure to stent the airway open.

Airflow Measures

Spirometry is a cost-effective and accessible tool for monitoring the presence of upper airway obstruction.[46,47] In the setting of infraglottic LTS, inspiration increases negative intratracheal pressure, leading to dynamic narrowing of the airway and tapering of inspiratory flow. In the expiratory phase, positive intratracheal pressure reexpands the airway, relieving the obstruction. When demonstrated on a flow-volume loop, this pattern is classically called a "fixed extrathoracic airway obstruction" (**Fig. 2**). However, this pattern may not manifest until the trachea's diameter is at least 6 to 8 mm.

In recent decades, there have been queries regarding the utility of spirometry as a way of predicting the optimal time to repeat intervention. Several function testing parameters have been interrogated as possible metrics for upper airway obstruction monitoring. The most common is the peak expiratory flow (PEF) and the expiratory dyspnea index (EDI). In a prospective cohort study of women with iSGS, a PEF of less than 4.4 L per second had a sensitivity and specificity of 84.4% and 82.0%, respectively, of repeat procedures within the next 2 months.[48] The Expiratory Disproportion Index is a ratio of forced expiratory volume in 1 second (FEV_1) to the peak expiratory flow-rate and has the highest sensitivity (88%) for predicting future endoscopic intervention. Values greater than 50 are indicative of clinically significant stenosis.[48,49] Additionally, the FEV_1/forced vital capacity has the highest specificity (85%).[48,49]

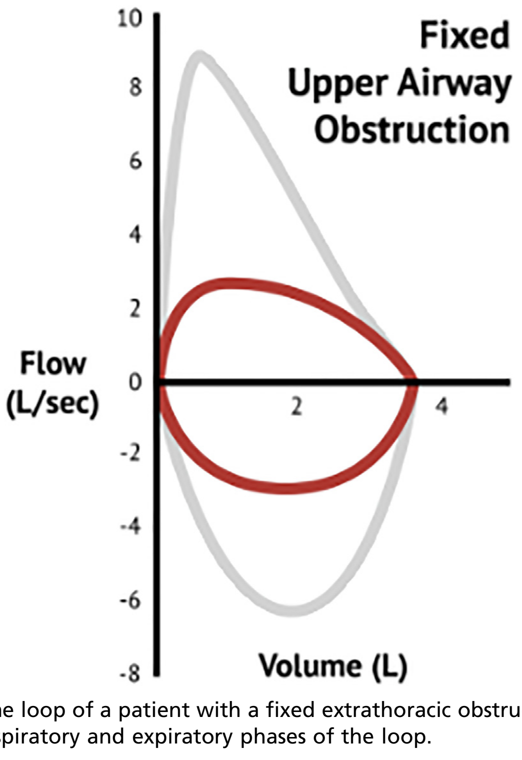

Fig. 2. A standard flow-volume loop of a patient with a fixed extrathoracic obstructive process (*red*). Notice the significant blunting of the inspiratory and expiratory phases of the loop.

There is increasing interest in the use of impulse oscillometry (IOS) for patients with central and peripheral airway obstruction.[50] This technique involves sound waves during normal tidal breathing, which gives information on oscillatory pressure-flow relationships and eventually resistance and reactance. IOS could be especially useful for an earlier detection of airway stenosis and in patients who cannot cooperate with spirometry maneuvers, such as children or patients with neurologic disorders.[51] In addition, this technique may be able to distinguish between upper/central and peripheral airway flow limitation, which can often be confounding in patients with concurrent LTS and chronic obstructive pulmonary disease, but more studies are needed to clarify the role of IOS in these circumstances.

SUMMARY

The etiology of the LTS is important to clarify in the initial workup and to plan an appropriate medical and surgical approach, which allows for more accurate and informed discussions regarding prognosis. Endoscopic techniques are considered as the first-line techniques in contemporary practice. Failure of endoscopic procedures or complex lesions requires open surgical techniques or airway stenting. In all cases, benign airway stenosis warrants a multidisciplinary approach to management, including but not limited to pulmonologists, otolaryngologists, thoracic surgeons, gastroenterologists, and speech-language pathologists, and anesthesiologists.

CLINICS CARE POINTS

- Benign Laryngotracheal stenosis (LTS) is most frequently caused by upper airway trauma related to prolonged endotracheal intubation. For patients without an obvious iatrogenic or traumatic etiology, a work-up for an underlying inflammatory/autoimmune, infectious, and neoplastic condition is warranted.
- Flexible bronchoscopy under general anesthesia is used to determine the presence of morphologic characteristics that may guide surgical planning, such as cicatricial glottic or supraglottic involvement, cricoarytenoid joint fixation, or secondary airway lesions.
- Endoscopic interventions with or without pharmacologic adjuncts such as inhaled or injected corticosteroids, topical MMC, and oral antibiotics, are considered first-line options for LTS. Open reconstruction or airway stenting may be considered after a failure of sequential methods or if contraindicated.
- Glottic enlargement strategies often apply to both posterior glottic stenosis and bilateral vocal fold paralysis. However, the distinction in diagnosis must be made to reinforce realistic patient expectations regarding achievable voice quality and respiratory status.
- First-time, simple tracheal stenoses (<1 cm) are amenable to endoscopic dilation alone or laser- or electrocautery-assisted radial incisions followed by mechanical dilation with rigid bronchoscopy. Complex lesions (length > 2–3 cm, circumferential, chondritis) frequently require open resection or silicone airway stenting.
- For patients with autoimmune-related LTS, an effective immunosuppressive regimen maximizes postoperative outcomes and mitigates the need for multiple surgeries. Significant cartilaginous involvement warrants tracheostomy placement.
- Spirometry or impulse oscillometry assists in monitoring the presence of upper airway obstruction and determining the optimal time for repeat intervention.

DISCLOSURE

The authors have no conflicts of interest to declare and no financial disclosures to report.

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