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A bronchoscopic approach to benign subglottic stenosis

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Abstract

Objectives: Subglottic stenosis is an abnormal narrowing of the tracheal lumen at the level of subglottis (the area in between the vocal cords and the cricoid cartilage). It can cause significant symptoms due to severe attenuation of airflow. We describe our experience in alleviating symptoms by addressing the stenosis using fibreoptic bronchoscopic methods.

Methods: We report all concurrent cases performed between September 2015 and July 2016. We use a combination of balloon dilation, electro-surgery knife to dilate and incise stenotic segments followed by steroid injection to modulate healing.

Results: We treated 10 patients in the study period, 8 of which were women. A total of 39 procedures were performed on these patients during this period. Gastro-esophageal reflux was the most common comorbidity associated with stenosis. The majority of the patients required more than 2 therapeutic procedures, but none required more than 4 procedures. There were no complications.

Conclusion: Tracheal stenosis and in particular subglottic stenosis is a recurrent process and its management requires extensive collaboration amongst treating specialties. Our technique of steroid injection after dilation of the stenosis was effective in symptom control and decreased the number of repeat procedures.

Keywords

Bronchoscopy, tracheal stenosis, dilation

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Introduction

Tracheal stenosis (TS) is an abnormal narrowing of the tracheal lumen, which can affect adequate airflow and causes significant pulmonary morbidity. It can occur at any anatomical level. TS refers to narrowing of the airway lumen from the cricoid cartilage to the main carina. Subglottic stenosis (SGS) refers to airway narrowing in between the glottis (i.e. vocal cords) and the cricoid cartilage. Laryngotracheal stenosis (LTS) encompasses any obstruction involving the larynx and/or the trachea. TS can be congenital but is usually acquired. Acquired TS can be caused by a wide range of pathologies including tracheal trauma, infections, non-infectious, neoplastic, and iatrogenic causes. The most common cause of TS is endotracheal intubation.[1,2]

The natural disease of TS can be classified into two phases: early, with primarily granulation tissue, and late, with hard fibrotic scarring.[3,4] Time from TS development to first intervention is also important. One study in post-intubation TS established that 90% of patients who had intervention within 6 months of extubation had a positive outcome compared to 61% of those with a longer delay before intervention.[5] Other reports have mirrored these findings showing that early recognition and treatment of lesions in the early phase may lead to favorable long-term outcomes, longer intervention-free interval, and prevention of complications, which can get increasingly difficult to address.[4,6]

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Treatment of TS remains unclear and challenging. Surgeons especially otolaryngology (ENT) have traditionally managed it and many physicians consider surgical resection as the first and best option. Early studies suggested that endoscopic treatment was less effective for circumferential disease and for stenosis greater than 1 cm in length.[7,8] Recent studies have demonstrated that involvement of the cricoid cartilage and stenoses over 3 cm are associated with an even more reduced chance of success.[9,10] Galluccio et al.[8] proposed the classification of TS into simple and complex, with simple stenosis defined as those less than 1 cm in length with no associated tracheomalacia or loss of cartilaginous support.

Endoscopic procedures can be considered in simple stenosis, as a bridge to definitive surgical intervention or for patients deemed at high risk for surgical intervention. However, with the recent advances in the field of interventional pulmonology, definitive management of TS using minimally invasive endoscopic methods became increasingly common.[11,12] Examples of endoscopic methods that have been used include mechanical dilation with the barrel of the rigid bronchoscope, balloon dilation, laser resection, cryotherapy, electrocautery, photodynamic therapy, stent insertion, and local treatments such as steroids, 5-fluorouracil, and mitomycin C.[4–6,11–14] Although the traditional approach is to use rigid bronchoscopy for endotracheal intervention, other centers have described using flexible bronchoscopy to intubate, dilate, and stent patients with TS without complication.[15]

We aim to describe our experience in the management of TS with flexible fiberoptic bronchoscope. All of the cases had been referred to us by ENT and our approach has been formulated in concert with them.

Case section

All bronchoscopic procedures were performed by the physicians of Division of Interventional Pulmonology at our institute in the bronchoscopy suite or the operating room (OR); an interventional fellow was involved in all cases. Consecutive referred patients between September 2015 and July 2016 presenting with TS were reviewed for the study.

All cases were performed with a BF-1T 260 flexible fiberoptic bronchoscope (Olympus Medical Systems), which has a 2.8-mm working channel. The procedures were performed under conscious sedation with propofol; local anesthesia was achieved with a combination of nebulized 4% lidocaine in the pre-operative phase and 2% lidocaine sprayed directly during the case. This was supplemented by either nasal or oral administration of oxygen and routine monitoring with pulse oximetry, arterial tension, and electrocardiogram.

When performed in the OR, the cases were performed after the airway was secured with a rigid bronchoscope or laryngeal mask airway (LMA). We use a LMA in patients with rigidity or instability of the cervical spine.

Table 1. Severity of stenosis based on percentage obstruction of lumen.[16]

Grade	Percentage obstruction of lumen
1	0%–50%
2	51%–70%
3	71%–99%
4	No detectable lumen

The combination of interventions employed included CRE (controlled radial expansion balloons; Rigiflex Balloon Dilator, Microvasive Watertown, MA and Witzel Pneumatic Dilator, M-T-W-W Buderich, Germany) balloon dilation, incision using a reusable electrosurgery knife (Olympus medical systems, Tokyo, Japan) using a current (25 W) delivered from the high-frequency electrical generator VIO 3000 (ERBE, Tübingen, Germany), and intralesional steroid, Kenalog®-40 Injection (triamcinolone acetonide injectable suspension, USP) into the area of the stenosis using an injection needle (Carr-Locke 25 gauge injection needle, US Endoscopy).

The type of stenosis was defined as "simple" (non-complex) if short (<1 cm), regular, and concentric, or as "complex" if irregular, large, and involving the subglottic space, two or more sites of the trachea, or associated with tracheomalacia.[8] In addition, the Myer et al.[16] classification was used (see Table 1).

Flexible fiberoptic bronchoscopy under deep sedation was well tolerated and safe for determining luminal characteristics of the stenosis including its length when the passage of the scope through the stricture was possible (100%). Computed tomography (CT) of soft-tissue neck was obtained to plan potential options prior to the procedures.

The patients had a planned treatment every 6 weeks for four procedures, with surveillance bronchoscopies at least up to 1 year after the fourth intervention.

The decision to base the therapy depended on the neck flexibility and anatomy of the stenosis (i.e. thicker and more fibrotic stenosis were incised and dilated and the thinner strictures were just dilated); the method of dilation was the barrel of a rigid or a CRE balloon. The hypothesis behind the less use of heat application is that it is likely to promote further fibrotic scar, which would be counterproductive to the goals of the procedure. We use prosthesis based on history of patient compliance and patient preference.

Case description and results

Patient 1. A 66-year-old man presented with TS due to fracture of anterior tracheal wall after a tracheostomy, granulation tissue, and circumferential fibrosis. Symptoms and the abnormality persisted in spite of multiple procedures by ENT including excision of granulation tissue and balloon dilation. Our bronchoscopy showed edematous subglottic

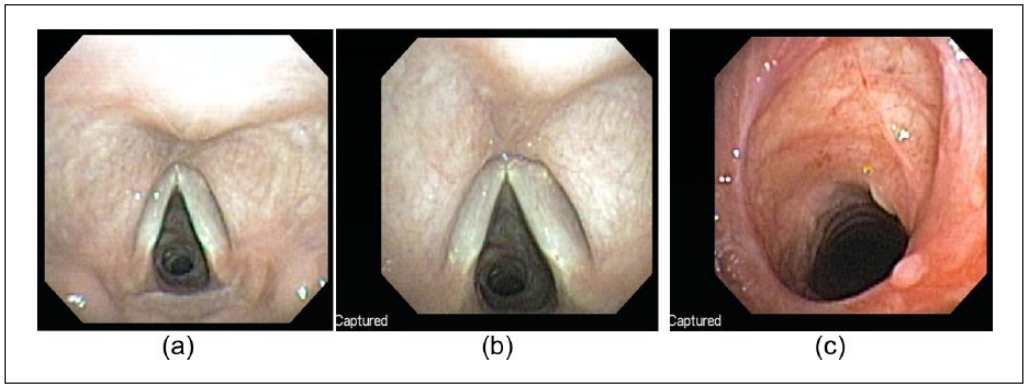

Figure 1. (a) Bronchoscopic image showing a 6-mm subglottic stenosis about 14 mm below vocal cords, (b) stenosis immediately after balloon dilation and Kenalog injection dilated up to 12 mm, and (c) follow-up bronchoscopy after 2 months showed the stenosis to be 11 mm in the subglottis.

area with granulation tissue 2 cm below the vocal cords with some dynamic airway collapse. Kenalog was injected into area of active granulomatous inflammation in a circumferential manner. Follow-up laryngoscopy showed complete resolution of stenosis but not the dynamic collapse; however, this did not lead to any symptoms. Patient continues follow-up with no recurrence.

Patient 2. A 28-year-old lady presented with obstructive sleep apnea (OSA), gastro-esophageal reflux disease (GERD), and morbid obesity, with progressive dyspnea and chronic cough. She had history of intubation for 10 days. A grade 1 SGS was found upon laryngoscopy. She continued to have symptoms despite balloon dilation to 15 mm. Our initial bronchoscopy revealed 70%–80% SGS (grade 2). She was deemed too high risk for operative intervention including rigid bronchoscopy. A total of four intervention procedures were performed over a period of 6 months including use of reusable electrosurgery knife (we made two radial cuts on a shelf of fibrotic segment), Kenalog injections, and removal of a friable membranous coating. Patient has been asymptomatic since the procedure and did not require any further dilatations.

Patient 3. A 54-year-old lady with Still's disease, chronic GERD was evaluated for chronic stridor, cough, and dyspnea. CT of soft-tissue neck showed eccentric thickening of subglottic trachea 14 mm below the true vocal cords. Bronchoscopy revealed a 9-mm stenosis which was 15-mm long (Figure 1(a)–(c)). Pathology showed fragments of benign fibrous tissue and respiratory epithelium with focal chronic inflammation. Patient underwent balloon dilation twice up to 12 mm and Kenalog injection during the third procedure, with excellent results. No further procedures have been needed.

Patient 4. A 74-year-old lady was assessed for subacute dyspnea and hoarseness. Her history was significant for GERD and prolonged intubation (10 days) after a cardiac arrest. CT of the neck revealed significant narrowing of the trachea (8 mm × 5 mm) at the level of cords due to a predominantly left-sided mass. Bronchoscopy confirmed the presence of a polypoid lesion along the posterior subglottic trachea that occluded approximately 33% of the tracheal lumen. The lesion was excised using an electrosurgery knife. Pathology showed granulation tissue with acute and chronic inflammation with no evidence of malignancy. Repeat bronchoscopy 2 months later demonstrated a heaped area of granulation tissue on the posterior tracheal wall causing partial stenosis up to 50% of the tracheal lumen. Kenalog injection and successful excision was performed. Three months later, patient had partial recurrence of symptoms and polypoid mass with 25% stenosis, which was excised and injected with Kenalog, this time without any recurrence.

Patient 5. A 57-year-old lady with history of transverse myelitis, GERD, and atrial fibrillation was evaluated for chronic cough, dyspnea, globus sensation, and hoarseness. Her history was complicated by TS (due to prolonged intubation) after which she underwent a tracheostomy. This was followed by a tracheal resection 4 years ago. At this time, she underwent a bronchoscopy that demonstrated 50% stenosis in the upper one-third of the trachea with dynamic collapse. Kenalog 40 was injected at level of stenosis and at the granulation tissue proximal to it. The repeat bronchoscopy demonstrated no re-stenosis. Surveillance laryngoscopies by ENT have documented stability of the TS.

Patient 6. A 50-year-old lady with long-standing grade 1 SGS was referred to us. She had undergone multiple micro direct laryngoscopy in the last 3 years with balloon dilation, lysis of scar tissue, without resolution of her symptoms. She also used courses of oral steroids intermittently during this period. On bronchoscopy, an area of SGS of approximately 50% was seen 10 mm below the vocal cords with inflammatory changes in surrounding tissues. We performed Kenalog

injections in circumferential manner around the stenosis in four different sittings over 6 months. Most recent bronchoscopy showed some stenosis, but the tracheal diameter was 12 mm.

Patient 7. A 69-year-old lady with GERD and morbid obesity was assessed for chronic progressive dyspnea. Bronchoscopy was performed based on suspicion of SGS on CT of neck, which showed two distinct stenosis 10 and 20 mm from the vocal cords. The proximal stenosis responded well to balloon dilation. The distal stenosis required multiple balloon dilations, use of needle knife followed by balloon dilation, and Kenalog injection. Pathology showed reactive squamous mucosa with chronic inflammation on pathology. She required three procedures over 3 months with a combination of balloon dilation and Kenalog injections, with resolution of both stenoses.

Patient 8. A 65-year old-lady with GERD who had known SGS for 7 years. She had multiple dilation procedures performed by ENT but had recurrence of symptoms. On bronchoscopy, a mild SGS with associated inflammation was seen (Figure 2(a) and (b)). After needle knife incision and Kenalog injection, a repeat bronchoscopy showed improvement in stenosis with decreased inflammation and minimal whitish secretions. She has had no further need for therapeutic procedures.

Patient 9. An 18-year-old lady with recent intubation (for 4 days) for a traumatic brain injury (TBI) presented with dyspnea. Microdirect laryngoscopy revealed a grade 3 SGS, which was 15 mm in length and located 50 mm below true vocal folds. Balloon dilation was performed up to 10 mm and a scar band was incised. She had continued dyspnea and wheezing. Bronchoscopy was performed which showed 50% stenosis at the described site. Two small cuts were made using electrosurgery followed by balloon dilation and Kenalog injection in all quadrants. Her symptoms improved and on subsequent bronchoscopy stenosis had resolved and she has had no further need for interventions.

Patient 10. A 45-year-old man with known OSA and history of tracheostomy. On bronchoscopy, approximately 20 mm below the vocal cords was a complex stenosis with granulation tissue. Areas of granulation and scar were ablated using argon plasma photocoagulation (APC). Electrocautery knife was used to make three radial incisions as well as incise an area of bridging fibrosis. As a final intervention, Kenalog was injected into the area of greatest inflammation. The repeat bronchoscopies have demonstrated stability.

While this is a case series, it is a series of relatively uncommon process obstruction and we present an analysis of our experience as well.

A total of 10 patients were included: 8 females and 2 males. Mean age was 52.6 years (range: 18–74 years). All patients underwent fiberoptic bronchoscopy. There were no severe complications related to the procedures, and the commonest procedure was post-procedural cough and pain.

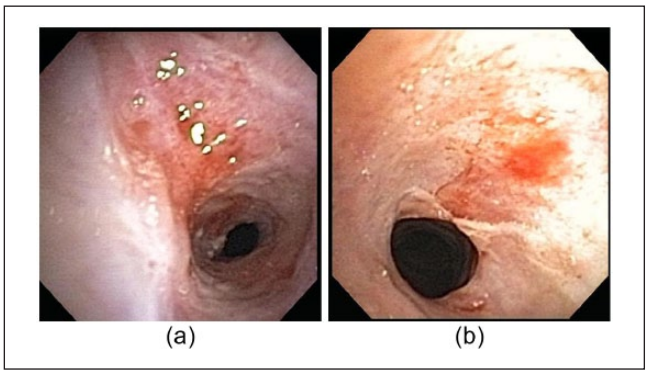

Figure 2. (a) Bronchoscopic image showing 7-mm subglottic stenosis and (b) patient underwent incisions with needle knife and Kenalog injection with improvement in stenosis to 10 mm.

Most patients had an intubation-related TS and the subglottic area was the most common area affected. The severity of the stenosis was mild by Cotton Myer grading (Table 1); however, these patients were symptomatic enough to warrant endoscopic intervention.[16] Most of our patients had medical comorbidities, which made them poor surgical candidates. GERD was the most common possible variable for persistent disease in our small series.

Most patients required multiple interventions and more than two administrations of steroids; however, no patient has required more than four therapeutic bronchoscopies. Kenalog®-40 Injection (triamcinolone acetonide injectable suspension, USP) is supplied in vials providing 40 mg triamcinolone acetonide per milliliter. On average 40–60 mg was administered per patient per session.

Table 2 summarizes the interventions performed during the study period.

Discussion

There are a multitude of causes of LTS, with post-tracheostomy (PTTS) and post-intubation (PITS) being most common.[17] PITS develops as a result of mucosal ischemia at the cuff site which can induce granulation tissue and scar development. This same mechanism can also result in PTTS; however, tracheal ring fracture associated with tracheostomy placement can cause destruction of cartilaginous support resulting in complex stenosis. Idiopathic LTS is a relatively rare condition, seen predominantly in females, which occurs in the subglottic area. Its mechanism is unclear, but there is a strong association with gastro-esophageal reflux and some experts believe it may be hormone dependent as it is seen in females of childbearing age.[18] LTS can develop following external beam radiation or endobronchial treatment of central airway tumors.[19] A variety of infectious etiologies can

Table 2. Summary of stenosis location and interventions performed during the study period.

Patient #	History of intubation	Location of stenosis	Type of intervention
1	History of intubation unavailable	Fracture of anterior tracheal wall after a tracheostomy	Kenalog° × 1
2	Intubated for 10 days	Subglottic stenosis	Four radial incisions and Kenalog
3	No history of intubation	Subglottic stenosis	Balloon dilation twice and Kenalog on third procedure
4	Intubation for 10 days	Posterior subglottic trachea	3× excisions with electrosurgery knife and Kenalog injection with last two excisions
5	Intubation (unknown duration)	Upper one-third of the trachea	Kenalog × 1
6	No history of intubation	Subglottic stenosis	4× Kenalog injection
7	No history of intubation	Subglottic stenosis	Balloon dilations, use of needle knife followed by balloon dilation, and Kenalog injection (three procedures)
8	History of intubation unavailable	Subglottic stenosis	Kenalog injection × 1
9	Intubated for 4 days	Subglottic stenosis	Balloon dilation was performed up to 10 mm and a scar band was incised. Two small cuts were made using electrosurgery followed by balloon dilation and Kenalog injection in all quadrants
10	History of tracheostomy	Subglottic stenosis	Areas of granulation and scar were ablated using argon plasma photocoagulation (APC). Electrocautery knife was used to make three radial incisions as well as incise an area of bridging fibrosis followed by Kenalog injection

result in LTS including tuberculosis, histoplasmosis, and *Klebsiella rhinoscleromatis* with the stricture often presenting long after the primary infection.[20–22]

The degree of airway narrowing may be more physiologically relevant to the patient's symptoms than the vertical extent of the stenotic segment.[23] The work of breathing depends on the pressure change along the stenotic segment and is influenced by both the degree of obstruction and the velocity of flow through the stenotic segment. In mild stenosis (i.e. ≤50% reduction in the cross-sectional area (CSA)), pressure drop is similar to that which occurs through the normal glottic opening and therefore is unlikely to cause symptoms. Moderate stenosis (51%–70% obstruction) can produce variable symptoms with relevant pressure drops occurring at higher flow rates during exercise. Severe stenosis (>71% reduction in CSA) results in significant pressure drops even at low flow, causing symptoms at rest or with mild exertion, and warrants intervention. These parameters comprise the Myer et al.[16] classification system which was shown to predict treatment outcomes and has been applied by otolaryngologists for several decades.

CT can assist in quantification of narrowing but obstruction can be overestimated by luminal secretions and the timing of image capture in relation to the respiratory cycle.[24,25] Assessing degree of narrowing by still images obtained during flexible bronchoscopy can also be challenging with subjective assessments varying based on technical factors, such as patient position or respiratory effort, and the experience of the bronchoscopist.[26] Peak expiratory to inspiratory flow ratio, endoscopic appearance on serial examination, and subjective symptoms have all been used as measures of success; however, there is no clear standard. In most cases, a combination of subjective symptoms and endoscopic findings of recurrent stenosis are used to gauge the need for additional therapies.

The surgical management of LTS usually depends on the anatomical level of the stenosis in addition to other considerations. TS refers to narrowing of the airway lumen from the cricoid cartilage to the main carina. SGS refers to airway narrowing in between the glottis (i.e. vocal cords) and the cricoid cartilage. LTS encompasses any obstruction involving the larynx and/or the trachea. The location of stenosis also affects management decisions and outcomes and thus this criterion must be included in the classification systems of LTS. In general, stenotic segments involving the larynx are not amenable to simple circumferential resection due to the anatomic course of the recurrent laryngeal nerve and require anterior resection of the cricoid cartilage, performed through a cervical incision, with sparing of the posterior cricoid plate.[27] Resection of stenotic segments in the upper trachea, without involvement of the subglottic space, requires surgical incision to be made slightly lower, just above the manubrial notch, and for thoracic tracheal resection median sternotomy may be required.[28] Disease occurring in the distal trachea, or with involvement of the proximal bronchi, is challenging to resect and often requires anastomosis of the proximal aspect of the trachea with the main bronchi creating a neocarina. Laryngeal resection with a sleeve technique is the gold standard for benign LTS management. The success of surgical procedures in benign TS varies widely. In a meta-analysis published in 2001, the success rate of laryngotracheal reconstruction (95%) is significantly higher than

that of laryngoplasty (76%) or endoscopic intervention (40%–82%).[29] However, surgery is not without risk. Mortality in the surgical approach has been reported to be up to 5%, and operation failure rates vary from 5% to 15%.[30,31]

A detailed discussion of endoscopic management of TS is relevant to our approach. Galluccio et al.[8] reported a 69% success rate for complex TS with endoluminal treatment and proposed a multidisciplinary approach for patients having complex stenoses.

Cavaliere et al.[32] reported favorable results in the treatment of both simple and complex tracheal stenoses. They reported a 100% success rate for web-like stenosis and a 22% success rate for complex TS and emphasized the importance of an appropriate bronchoscopic, clinical, and radiologic evaluation to improve the outcome of endoscopic treatment.

Bronchoscopic balloon dilation is a simple, nontraumatic, rapid method to dilate a stenosis and restore adequate airflow. It may be used in combination with other techniques such as laser resection, bougie dilation, cryotherapy, or electrocautery. While balloon dilation can be done via either flexible or rigid approach, rigid bronchoscopy provides better control of the airways along with proper ventilation for the patient. The stenotic trachea can be dilated with the barrel of rigid bronchoscope; however, balloon dilation is definitely the safer alternative. Overenthusiastic dilation should be avoided as it can lead to extraluminal damage with subsequent scarring or more dangerously tracheal rupture. Endoluminal balloons may be gentler by providing uniform radial pressure on the stenotic segment without damaging the mucosa. The choice of the balloon's diameter depends on the normal caliber of the airway. Once a lumen is established, the deflated balloon is advanced to straddle to the stenotic segment and gradually inflated to the required size.

Neodymium-doped yttrium aluminum garnet (Nd-YAG) laser irradiation and stenting[33] have been traditionally used as a first step in the treatment of benign TS. While lasers are known to be an effective modality for treating airway obstructive lesions; the operator should be careful to avoid extensive damage to the bronchial wall, leading to further cartilaginous damage, fibrosis, and subsequent endoluminal stenosis.[34,35] Argon plasma coagulation safely devitalizes the stenotic region, allowing removal with grasping forceps. Radial incisions can be made using neodymium-doped yttrium aluminum garnet (Nd: YAG) laser (using high-power density to avoid collateral tissue damage), potassium titanyl phosphate (KTP) laser, or an electrocautery knife. If an electrocautery knife is used, it is safer to use the blend or coagulation mode, rather than the cut mode, in order to assure hemostasis. Airway management is usually done via an LMA rather than an endotracheal tube in an OR setting. This technique allows for improved airway control and the ability to provide ventilation and simultaneous close-up visualization of the stenosis with full exposure of the operative field.[36] The LMA technique offers the added benefit of establishing a completely closed and secured airway and avoids some of the risks associated with jet ventilation, such as a pneumothorax. There is also a reduced risk of airway fires when compared to an endotracheal tube, although the risk is low when using laser compatible endotracheal tubes.[37]

Stents can be inserted either during the first attempt or after failure of simple dilation to maintain the lumen until it is stable.[38] In some patients, stents can be used as a temporizing measure until more permanent surgery is possible. For benign stenoses, silicone removable stents are usually recommended. They are inserted for a variable period, usually 6 weeks and up to 1 year. After the lumen is deemed stable, they can be removed. Although stents offer an attractive alternative to open surgical techniques, they are not without their own complications. A strict technique in application and follow-up are mandatory to prevent life-threatening complications.

More recently, cryo-spray therapy (Trufeeze® CSA Medical Inc) has shown promising results;[39] however, the cost to install a unit is approximately US$90,000, which can be burdensome to institutions without high volume of cases.

The overall results have been variable. In one study, the etiologies of airway stenosis included intubation injury,[6] idiopathic,[4] or autoimmune disease,[1] and the number of dilations that were required were 1.3, 1.5, and 3, respectively.[7] Average operative time was 67 min. Autoimmune etiology correlated with more frequent dilations.

The traditional flexible fiberoptic bronchoscopic method to managing SGS generally includes radial incisions of the stenotic airway segment, dilation, and adjunctive treatment with steroids or mitomycin C.[12–16] Mitomycin is the drug most commonly used. Various concentrations were advocated (0.1 up to 10 mg/mL). However, the concentration is usually 0.4 mg/mL and is applied topically on a cottonoid pledget. The length of application varies from two to three repeat applications of 2 min each to a single application of 5 min. In one study, endoscopic laser radial incisions with mitomycin C application had been shown to result in a temporary reduction in symptoms.[40] In another retrospective case series of 15 patients, six patients (40%) required only one procedure and nine patients (60%) required repeat procedures at an average interval of 9 months.[41]

Table 3 summarizes the findings and results of various modalities of interventions for LTS previously published in the literature.

The mechanism of action of intralesional steroid injection is not completely clear. Intralesional steroid injection is known to decrease collagen synthesis and fibrosis.[42] Triamcinolone decreases the synthesis of a collagenase inhibitor, α_2-macroglobulin.[43] It has also been suggested that triamcinolone prevents the cross-linking of collagen that results in scar contracture, so that if the scar is stretched and corticosteroid is injected into it, contracture will presumably not occur.[44] Corticosteroids also decrease post-dilation fibrotic healing.[42] Intralesional steroid injection has also been used successfully for management of resistant strictures of the gastrointestinal tract.[45]

Table 3. Summary of previously reported case series on various modalities of interventions for laryngotracheal stenosis.

Reference	Number of patients	Etiology and nature of stenosis	Interventions	Outcomes
Roediger et al.[41]	15	Wegners and idiopathic	Laser with mitomycin C (MMC)	Six patients (40%) required only one ELRM and nine patients (60%) required repeat ELRM at an average interval of 9 months
Smith and Elstad[40]	26	Idiopathic, post-intubation and Wegners	CO_2 laser incision and dilation, MMC	The relapse rates at 1, 3, and 5 years were 7%, 36%, and 69% for two applications of MMC versus 33%, 58%, and 70% for one application of MMC
Fernando et al.[39]	35	Post-intubation, prior tracheostomy, radiation induced, prior surgery	Spray cryotherapy (SC) and balloon dilation	17 (49%) patients required additional SC therapy, resulting in a total of 63 SC treatment sessions
Koufman et al.[37]	13	Subglottic	CO_2 laser	77% of these patients had a satisfactory airway reestablished within a 1-year period
Cavaliere et al.[32]	73	Weblike and complex subglottic stenosis	Laser-assisted mechanical dilation and stent	22 had stents removed after 1 year, 13 required permanent stent and 12 were referred to surgery after failure of endoscopic therapy
Coulter and Mehta[34]	47	Tracheal stenosis presenting for Nd-YAG laser photoresection (LPR)	Endobronchial electrosurgery	42 (89%) were successful in alleviating the obstruction, thus eliminating the need for laser photoresection
Nouraei et al.[5]	31	Post-intubation	Laser, balloon dilation, and MMC	Patients treated for acute injury required significantly fewer interventions ($p < 0.03$), the majority being treated with a single treatment
Galluccio et al.[8]	200	Post-intubation, post-tracheostomy, and other	Laser photoresection, mechanical dilation, and placement of a silicone stent	Overall success rate was 96%. For complex stenoses, the success rate was 69%
Bhora et al.[14]	26	Granulomatosis with polyangiitis (GPA), prior tracheostomy or intubation, and idiopathic strictures	SC and balloon dilation	In a median (range) follow-up of 11 (1–26) months, all patients had improvement in symptoms. After SCT, the rate of grade III or IV stenosis went from 88% to 15%
Lim et al.[4]	55	Post-intubation	Laser cauterization, mechanical bougienation and ballooning followed by silicone stent	The stents were removed successfully in 40% (22/55) of the patients after median 12 months of stenting
Raman et al. (current series)	10	Idiopathic and post-intubation stenosis	Electrosurgery knife, balloon dilation, Kenalog injection	39 procedures were performed during 1-year period for 10 patients. All patients remain asymptomatic and follow-up bronchoscopy shows stable stenoses

ELRM: endoscopic laser radial incisions with mitomycin-C application; SCT: spray cryotherapy.

All our patients were referred to us from ENT after having deemed to be non-surgical candidates either from medical comorbidities or having been assessed to not require surgery given the lack of severe symptoms with good functional status. As noted, most patients were middle aged with intubation-related TS in the subglottic area of mild to moderate severity. Our interventions ranged from steroid injection alone to a combination of modalities including balloon/rigid dilation with the goal to increase luminal patency and or radial incisions of scar tissue made with the reusable electrosurgical knife combined with balloon dilation. Most patients improved over time with these interventions and none of the patients have required more than four procedures, and most of these patients had already had more than 10 procedures prior to their referral to interventional pulmonology.

Our approach represents a cost-effective minimally invasive way of intervening on the subglottic trachea with little risk and discomfort. This is in contrast to the expense involved with the endoscopic management described in detail above (laser incisions with dilation and mitomycin therapy).[37] In this series, the average cost of each CRE balloon was US$200, each LMA was US$9, and the Omni Guide ENT-L laser fiber was US$1300.[17] All products were designed to be single-use items. All our procedures are

completed in the outpatient setting and within an hour with a 30-min recovery time in the post-operative area prior to discharge. No complications were observed.

This article has its limitations: a small sample size and retrospective in nature. The aim of this article is to share our experience with the medical community.

Conclusion

SGS is a challenging condition and warrants a collaborative approach to management. Treatment should be a collaborative effort between specialties depending on the location, extent and shape of the stenosis, degree of airway lumen narrowing, etiology, and impact on patient's functional status. The lack of uniformity in qualitative and quantitative factors of this disease complicates the ability to develop meaningful recommendations for managing patients suffering from it. Despite this, bronchoscopic treatment should not only be reserved as a palliative alternative to surgical intervention but should be considered as a valid therapeutic option. Our technique for simple SGS is successful without being too burdensome for a process that is recurrent and insidious.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

Our institution does not require ethical approval for reporting individual cases or case series.

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Informed consent

Written informed consent was obtained from the patient(s) for their anonymized information, including bronchoscopy images, to be published in this article.

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