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A Comparative Study of Cricotracheal Resection and Staged Laryngotracheoplasty for Adult Subglottic Stenosis

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Abstract

Objective: Cricotracheal resection (CTR) and laryngotracheoplasty (LTP) are open surgical treatments for severe subglottic stenosis. This study aims to compare the applications and outcomes of these techniques.

Method: Patients with subglottic stenosis at a tertiary academic institution from 2000 to 2012 were identified by diagnosis codes. Patients who underwent LTP or CTR were included. Records were reviewed for treatment data and outcomes. Patients with a history of head and neck malignancy or stenosis without cricoid involvement were excluded.

Result: Sixty-one and 20 patients underwent LTP and CTR, respectively. When comparing patients receiving LTP and CTR, there was a significant difference in stenosis etiology (P = .014). The groups were similar in Cotton-Myer grade (P = .102). At last follow-up, 80.3% of LTP patients and 90.0% of CTR patients were decannulated. On multivariate analysis, there was a significant association between stenosis grade and decannulation in the LTP group (P = .01). Decannulation was not associated with stenosis grade in the CTR group. In both groups, there was no significant association between decannulation and sex, stenosis etiology, or stenosis length.

Conclusion: Cricotracheal resection and LTP have both shown excellent long-term decannulation rates. Etiology and stenosis grade are likely to be determining factors when recommending specific surgical interventions for subglottic stenosis.

Keywords

acquired subglottic stenosis, cricotracheal resection, laryngotracheoplasty

Introduction

Subglottic stenosis (SGS) in the adult patient persists as a modern challenge with complex management options and no standard treatment. Non-idiopathic stenosis often results from direct injury to the laryngotracheal mucosa, leading to chronic inflammation and narrowing of the airway. Multiple studies have found that more than 50% of patients with SGS have an etiology of intubation or tracheotomy.[1,2] Other causes of SGS include external cervical trauma, laryngopharyngeal reflux, and autoimmune disease (ie, granulomatosis with polyangiitis).[3,4]

The management of SGS must be tailored to the severity and location of pathology in each patient. Endoscopic treatments such as balloon dilation, CO_2 laser incision, and antineoplastic agent application are safe, well-tolerated, and often successful in mild SGS.[5] However, these conservative treatments may suffer from recurrence, and a significant portion of patients require multiple repeat procedures.[2] Definitive treatment with long-term decannulation can be achieved through open surgical approaches, but these carry greater risks.[4] The 2 general strategies of open surgical approaches include either a trough resection with reconstruction or complete resection with re-anastomosis: laryngotracheoplasty (LTP) or cricotracheal resection (CTR). Laryngotracheoplasty creates an expansion of the airway structure and excision of stenotic tissue without circumferential resection. Many variations of LTP have been described, including single-stage versus multistage approaches, various artificial or native grafts, and methods

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of tracheal stenting.[6] Cricotracheal resection involves segmental resection of the stenotic airway and end-to-end anastomosis. Various laryngeal and tracheal release techniques have been described,[7,8] which generally allows for resection of up to about 12 tracheal rings or 6 cm of airway.

Previous comparative studies evaluating the surgical management options for adult SGS have been reported with small sample sizes.[2,3,9,10] In this study, we aim to review the largest experience of LTP and CTR in an adult cohort to compare the use of these 2 surgical approaches and identify clinical factors important in achieving permanent decannulation.

Materials and Methods

Institutional review board approval for the described methods was obtained prior to the initiation of this study.

Study Design

Patients were identified at a single tertiary university medical center by ICD-9 diagnostic codes (478.74 or 519.19) between the years of 2000 and 2012. Patients with subglottic stenosis who underwent multistaged LTP or CTR at the present institution were included. Inclusion criteria also included age of 17 years or older. Patients were excluded if the stenosis was strictly tracheal or reached superiorly into the level of the vocal folds (laryngeal stenosis). Patients with a history of malignancy within the aerodigestive tract were also excluded. Data were recorded through retrospective chart review.

Demographic and Clinical Characteristics

Recorded clinical data included age at presentation, sex, significant medical comorbidities, prior intubation, tracheostomy, etiology of stenosis, length of stenosis, and grade of stenosis. Medical comorbidity in each patient was classified and graded using the Charlson index,[11] which predicts 1-year mortality through a weighted total score of a patient's comorbidities. Etiology of stenosis was determined to be prolonged intubation if intubation duration was greater than 1 day and symptoms of stenosis were temporally associated. Stenosis was considered idiopathic if no other potential etiology was evident, including trauma, autoimmune disease, or recent prolonged intubation. The Cotton-Myer grading system was used to stage stenosis severity (grade I up to 50% stenosis, grade II 51%-70% stenosis, grade III 71%-99% stenosis, and grade IV 100% stenosis).[12] Cotton-Myer grade was employed over other grading systems because it is consistently used at this institution to describe SGS, and these data were available for all patients. Stenosis length was categorized into short (up to 2 cm) and long (> 2 cm in length) segments. Stenosis grade and length were determined with intraoperative laryngoscopy and bronchoscopy at the time of CTR or first stage of LTP. The primary outcome measure was long-term decannulation, which was defined as sustained decannulation at last clinical follow-up.

Surgical Techniques

Cricotracheal resection was performed as previously described.[3,13] Tension-relieving procedures were employed as needed, which included laryngeal release, cervical tracheal mobilization, or mediastinal tracheal mobilization to the carina. For a number of patients, tracheostomy was performed below the level of the anastomosis at the conclusion of CTR, and decannulation occurred after hospital discharge.

Staged LTP was performed in the following manner: The first stage began with direct laryngoscopy and bronchoscopy to characterize the stenosis. A vertical neck incision was created at the midline and anterior laryngofissure was performed. The stenosis was visualized and scar tissue was removed with sharp excision or a surgical drill. A buccal mucosa graft was harvested and sutured to cover the denuded luminal mucosa. A vertical open tracheal trough was then formed by suturing skin to the lateral edges of the tracheal walls. A stent was placed to bolster the graft, which may be a Montgomery T-tube (Boston Medical Products, Westborough, Massachusetts, USA) or a solid conforming material (Coe-Soft; GC America, Alsip, Illinois, USA) with a distal tracheostomy. After a period of 7 days, the second stage began with examination of the mucosal graft and debridement of any granulation tissue. If augmentation of the anterior tracheal wall was necessary, absorbable mesh (ie, Vicryl) of a size approximately equal to the desired anterior wall was burrowed in the subcutaneous tissue lateral to the open trough. This pocket was closed primarily, and at the conclusion of the second stage, a Montgomery T-tube was placed to allow for voicing function. Maturation of the mesh flap complex occurred over several weeks. During the third stage, the mesh and overlying skin were rotated medially to recreate the anterior tracheal wall with inversion of the skin edges into the lumen. The skin was then closed primarily in a vertical fashion. A T-tube may be placed to maintain the structure of the reconstruction and may be removed at a later date. Postoperative follow-up is tailored to each patient.

Statistical Analysis

Statistical analysis was performed using R version 3.0.2 (R Foundation, Vienna, Austria). Univariate unadjusted analysis was performed using Fisher exact test or chi-square test of proportions when appropriate. Logistic regression analysis was performed to determine independent predictors of decannulation. Predictive probabilities of decannulation based on grade of stenosis were determined with the marginal effects of the regression model. Independent variables included age, sex, surgeon, stenosis grade, stenosis etiology, stenosis length, and history of previous intubation. A P value ≤ .05 was considered to be statistically significant. The criterion for inclusion of independent variables in the logistic model is those with $P < .10$ on univariate analysis. If a variable did not meet this condition but was deemed to be clinically relevant, it was included in the logistic model.

Results

Between January 2000 and January 2012, 81 patients with subglottic stenosis met inclusion criteria. Sixty-one and 20 patients were treated with staged LTP and CTR, respectively. An additional 18 patients underwent resection-anastomosis but were excluded due to malignancy or a strictly tracheal stenosis. Mean age at the time of initial surgery was 47.1 years (range, 17-82 years) for LTP patients and 48.2 years (range, 31-72 years) for CTR patients. Mean follow-up from the time of initial surgery was 4.1 years (range, 0.2-17.3 years) for LTP patients and 3.8 years (range, 0.1-11.7 years) for CTR patients. Etiology of stenosis was most commonly prolonged intubation, trauma, autoimmune disease, and idiopathic (see Table 1).

Successful decannulation at last follow-up had occurred in 49 of the 61 patients (80.3%) who underwent LTP and 18 of the 20 patients (90%) who underwent CTR. The remaining patients failed decannulation attempts and remain tracheostomy or T-tube dependent. Unadjusted univariate analysis was performed to compare decannulated patients to those who failed decannulation. In the LTP group, there was a significant association between grade of stenosis and rate of decannulation ($P = .029$) but no significant association based on age, sex, Charlson index, etiology of stenosis, length of stenosis, and history of intubation (see Table 2). In the CTR group, decannulation was significantly associated with younger age ($P = .038$), lower Charlson index ($P = .021$), and shorter postoperative hospital stay ($P < .001$). There was a trend toward correlation between decannulation and grade ($P = .10$). No significant association with sex, etiology of stenosis, length of stenosis, history of intubation, type of anastomosis, type of mobilization, or tracheostomy (see Table 3) was seen.

For patients who underwent LTP, multivariate logistic regression showed a significant association ($P = .015$) between rate of decannulation and Cotton-Myer grade when controlling for age, sex, stenosis length, and previous intubation (see Table 4). With this logistic model, decannulation probability was determined according to Cotton-Myer grade with 95% confidence intervals (see Figure 1). To calculate probability values, other patient characteristics were kept constant using the mean for continuous variables and the mode for categorical variables (female sex, short length, and previously intubated). Patients with grade I or II stenosis undergoing LTP had a significantly greater probability of decannulation compared to those with grade IV stenosis. There was no significant difference between patients with grade III stenosis compared to other grades, and the decannulation rate of patients with grade III stenosis was between that of patients with grade II and IV stenosis. A logistic regression model could not be fitted to determine independent predictors of decannulation in patients who underwent CTR due to a low number of patients who failed decannulation.

Of the 81 surgical patients, 12 (14.8%) experienced perioperative complications. Three of the 12 complications were in the CTR group. One patient experienced a small anastomotic dehiscence, which resolved without intervention. One patient had a granuloma at the tracheostomy site 1 month after surgery, which required readmission. One patient experienced anterior tracheal wall infection requiring debridement and permanent T-tube placement. Nine of the 12 complications were in the LTP group. There was 1 case of mild paratracheal cellulitis that resolved with conservative treatment and 1 case of mesh erosion after the second stage requiring mesh removal. Two patients experienced mild pneumothoraces or subcutaneous emphysema, without the need for chest tube placement or other invasive intervention. The other 5 patients experienced T-tube complications. There were 3 cases of dislodged T-tubes requiring replacement in the operating room. One patient was readmitted due to mucus plugging his T-tube, and 1 patient required T-tube revision due to the superior limb being too close to the vocal folds. There were no mortalities in this series.

Discussion

In the management of subglottic stenosis with cricoid involvement, choosing the best open surgical option is frequently complex and challenging. Both CTR and LTP have been shown to have excellent decannulation rates. In recent large series, long-term decannulation rates with CTR up to 95% have been seen.[1,14,15] Similarly, LTP has been reported to have decannulation rates greater than 90%, although published reports often differ in types of grafting and stenting employed.[16-18] It has been suggested that CTR is superior to LTP based on published decannulation and additional surgical procedure rates in various studies.[9] However, comparisons of retrospective decannulation and reoperation rates at different institutions may be problematic. To date, there is no prospective study comparing these 2 surgical approaches in the adult population.

Despite high decannulation rates in the literature, published data have suggested that long-term outcomes of CTR are not equivalent to primary resection of a segment involving only the trachea. Negm et al[19] reported a series of 24

Table 1. Patient Characteristics.[a]

	No. (%)	LTP	CTR	*P* Value
Patients	81	61	20	
Age, y				.79
Mean	47.4	47.1	48.2	
Range	17-82	17-82	31-72	
Sex				.60
Female	47 (58)	34	13	
Male	34 (42)	27	7	
Charlson index				.25
0	47 (58)	32	15	
1	17 (21)	13	4	
2	7 (9)	7	0	
> 2	10 (12)	9	1	
Etiology of stenosis				.015[b]
Prolonged intubation	39 (48)	28	11	
Idiopathic	18 (22)	10	8	
Blunt laryngeal trauma	10 (12)	10	0	
Autoimmune disease	9 (11)	9	0	
Benign neoplasm	3 (4)	3	0	
Airway fire	1 (1)	1	0	
Laryngeal rhinoscleroma	1 (1)	0	1	
History of intubation				.38
Never intubated	21 (26)	14	7	
Previously intubated	59 (73)	46	13	
Stenosis length				.29
Up to 2 cm	49 (60)	39	10	
Greater than 2 cm	31 (38)	21	10	
Cotton-Myer grade				.102
Grade I	4 (5)	4	0	
Grade II	25 (31)	18	7	
Grade III	34 (42)	22	12	
Grade IV	16 (20)	15	1	
Follow-up, y				.41
Mean	3.8	4.1	2.8	
Range	0.2-17.3	0.2-17.3	0.2-11.7	
Decannulated	67 (83)	49	18	

Abbreviations: CTR, cricotracheal resection; LTP, laryngotracheoplasty.
[a]Significance was determined using Fisher exact test for categorical variables and Student *t* test for continuous variables.
[b]$P < .05$.

patients who received tracheal resection or CTR for postintubation stenosis. Cricoid involvement and cricoid resection were statistically associated with restenosis, with 4 of 9 CTR patients failing decannulation. Laccourreye et al[20] retrospectively reviewed 41 patients who underwent tracheal resection or CTR. Two of the 14 patients who underwent CTR required postoperative dilations to achieve airway patency and 1 patient failed decannulation, whereas the tracheal resection group had 100% airway patency with no additional procedures. In 1 patient who received CTR, bilateral vocal fold fixation occurred, requiring a posterior transverse cordotomy for decannulation. Abbasidezfouli et al[21] reported a series of 494 patients who underwent primary resection with 52 cases of restenosis. On multivariate analysis, independent predictors of restenosis included anastomotic infection, any cricoid resection, and presence of anastomotic tension. This suggests that LTP may yield improved outcomes in patients at risk for anastomotic tension, which includes stenoses approaching 6 cm.

The comparative study of LTP and CTR in pediatric SGS is readily available, as the pediatric experience of SGS is more extensive. However, the choice between these approaches has been an ongoing issue in the pediatric patient as well. Hartley and Cotton[22] recommended that in patients with low-grade stenosis, LTP should be used because it is a less extensive procedure that does not require

Table 2. Clinical Characteristics of Laryngotracheoplasty Patients: Decannulated vs Tracheostomy Dependent.[a]

	Decannulated (%)	Tracheostomy Dependent (%)	*P* Value
Total patients	49	12	
Age, mean (SD)	48.1 (16.9)	43.0 (15.6)	.354
Sex			.522
Female	26 (53)	8 (67)	
Male	23 (47)	4 (33)	
Charlson index			.96
0	26 (53)	6 (50)	
1	10 (20)	3 (25)	
2	6 (12)	1 (8)	
> 2	7 (14)	2 (17)	
Etiology of stenosis			.912
Prolonged intubation	21 (43)	7 (58)	
Blunt laryngeal trauma	9 (18)	1 (8)	
Autoimmune disease	8 (16)	1 (8)	
Idiopathic	8 (16)	2 (17)	
Other etiology[b]	3 (6)	1 (8)	
History of intubation			.217
Never intubated	13 (27)	1 (9)	
Previously intubated	36 (74)	10 (91)	
Length of stenosis			.312
Up to 2 cm	33 (69)	6 (50)	
> 2 cm	15 (31)	6 (50)	
Cotton-Myer grade			.029[c]
Grade I	4 (9)	0 (0)	
Grade II	16 (34)	2 (17)	
Grade III	19 (40)	3 (25)	
Grade IV	8 (17)	7 (58)	

[a]Significance was determined using Fisher exact test for categorical variables and Student *t* test for continuous variables.
[b]Other etiology includes benign subglottic neoplasms in 3 patients and airway fire in 1 patient.
[c]$P < .05$.

tracheal mobilization. In grade IV stenosis, the authors found similar decannulation rates of more than 80% for both LTP and CTR, but patients receiving LTP were more likely to require additional open procedures to achieve decannulation. Cricotracheal resection is not an option when there is not a clear margin (at least 3 mm) between the stenosis and vocal folds. Therefore, the authors recommend LTP in grade II and selected grade III patients, whereas CTR is recommended in severe grade III and grade IV patients. It is notable that the issue of increased repeat procedures in LTP has been suggested in the adult literature as well.[9]

In the present study, LTP and CTR were found to have decannulation rates of 80% and 90% at our institution, respectively. Laryngotracheoplasty was demonstrated to be significantly and inversely associated with Cotton-Myer grade, although there was no relationship with age, sex, etiology, or length of stenosis. Only 53% of patients with grade IV stenosis achieved decannulation with LTP, compared to 85% for less severe stenosis. These findings are consistent with a published series by Gallo et al.[23] Of 70 patients who underwent various surgical treatments for LTS, a significant inverse association between decannulation and Cotton-Myer grade was seen, with 94% and 50% of grade II and grade IV patients achieving decannulation, respectively. Wester et al[10] reported a series of 53 patients who underwent CTR or LTP and achieved decannulation in 78% and 40% of patients with grades I-III and grade IV stenosis, respectively. In the present study, no significant association was found between decannulation and stenosis grade in patients who underwent CTR, although this may be limited by sample size, with only 2 patients failing decannulation. Wolf et al[15] reported a series of 23 patients who received CTR for the treatment of subglottic stenosis. The authors found no significant association between stenosis grade and airway patency. The data presented here along with published studies raise the possibility that CTR is superior to LTP in patients with grade IV stenosis, but larger comparative studies are needed to further evaluate this question.

In patients who underwent CTR, we found that decannulation was significantly associated with age, Charlson

Table 3. Clinical Characteristics of Cricotracheal Resection Patients: Decannulated vs Tracheostomy Dependent.[a]

	Decannulated (%)	Tracheostomy Dependent (%)	*P* Value
Total patients	18	2	
Age, mean (SD)	45.9 (14.0)	68.8 (5.0)	0.038[b]
Sex			1.00
Female	12 (67)	1 (50)	
Male	6 (33)	1 (50)	
Charlson index			0.021[b]
0	15 (83)	0	
1	3 (17)	1 (50)	
2	0	0	
> 2	0	1 (50)	
Etiology of stenosis			0.54
Prolonged intubation	9 (50)	2 (100)	
Idiopathic	8 (44)	0	
Laryngeal rhinoscleroma	1 (6)	0	
History of intubation			0.52
Never intubated	7 (39)	0	
Previously intubated	11 (61)	2 (100)	
Length of stenosis			1.00
Up to 2 cm	9 (50)	1 (50)	
> 2 cm	9 (50)	1 (50)	
Cotton-Myer grade			0.10
Grade II	7 (39)	0	
Grade III	11 (61)	1 (50)	
Grade IV	0	1 (50)	
Anastomosis			1.00
Cricotracheal	10 (56)	1 (50)	
Thyrotracheal	8 (44)	1 (50)	
Mobilization			1.00
Tracheal-cervical	5 (28)	0	
Tracheal-mediastinal	10 (56)	2 (100)	
Infrahyoid + cervical	2 (11)	0	
Preop tracheostomy	5 (28)	1 (50)	0.52
Postop tracheostomy	11 (61)	1 (50)	1.00
Hospital stay, mean (SD), d	7.8 (2.3)	20.5 (12.0)	< 0.001[b]

[a]Significance was determined using Fisher exact test for categorical variables and Student *t* test for continuous variables.
[b]*P* < .05.

Table 4. Logistic Regression Results for Odds of Decannulation in Laryngotracheoplasty Patients.

	OR	95% CI	*P* Value
Age	1.01	0.956-1.05	.95
Sex			
Female	1		
Male	3.02	0.680-17.2	.17
Stenosis length			
Long	1		
Short	1.62	0.339-7.47	.54
Cotton-Myer grade[a]	0.253	0.081-0.640	.015[b]
Previously intubated	4.02	0.812-21.9	.089

Abbreviations: CI, confidence interval; OR, odds ratio.
[a]For every 1 unit increase in Cotton-Myer grade, the odds of decannulation decrease by a factor of 0.253.
[b]*P* < .05.

index, and hospital stay. The association between advanced age and poorer decannulation is not surprising and is consistent with other published series of CTR.[15,23] The relationship between decannulation and medical comorbidity has also been shown in the literature. Lano et al[5] reported a series of 22 cases of resection-anastomosis and found that medical comorbidities increased failure or increased the difficulty of decannulation, including diabetes, chronic obstructive pulmonary disease, and congestive heart failure. The observed difference in hospital stay length was due to a postoperative complication of anastomotic infection in 1 patient requiring tracheal debridement and persistent T-tube placement. T-tube dependence in this case is in line with previous studies showing anastomotic infection to be an independent predictor of decannulation failure.[21] In that study, anastomotic tension was also a predictor of

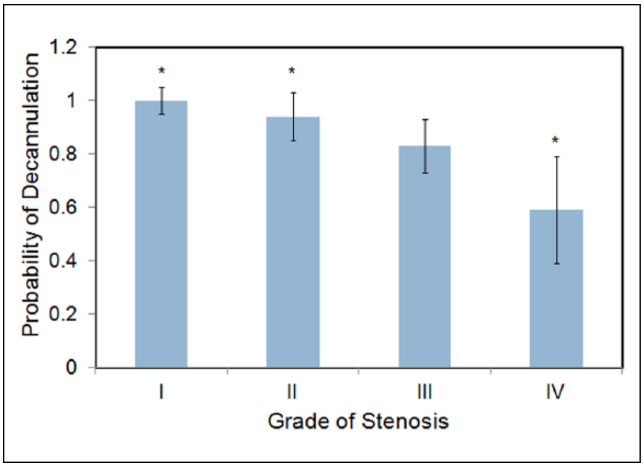

Figure 1. For patients who underwent laryngotracheoplasty, a logistic regression model was used to determine probability of decannulation based on Cotton-Myer grade with 95% confidence intervals. Other patient characteristics were kept constant using the mean for continuous variables and mode for categorical variables (female sex, short length, and previously intubated). A significant increase in rate of decannulation is found between grades I & II and grade IV (*P* = .01). For patients who underwent cricotracheal resection, probability of decannulation based on grade could not be calculated due to lack of convergence of the logistic regression model. *Statistical significance (*P* < .05).

decannulation failure, but stenosis length was not correlated with decannulation in our series, likely because of adequate tracheal mobilization.

In relation to the etiology of stenosis, all patients who presented to this institution with laryngotracheal stenosis as a result of trauma or autoimmune disease underwent LTP rather than CTR, resulting in statistically significant differences between SGS etiology between the 2 surgical groups. The 10 patients with an etiology of trauma include the following: 5 patients with stenosis near or contacting the vocal folds, 2 patients with prior LTP procedures at outside hospitals, 1 patient with a scar that would make tracheal mobilization difficult, and 1 patient with a severe cricoid fracture. Laryngotracheoplasty was chosen in those patients for anatomic reasons. Previous studies have shown that CTR is a viable option for the repair of traumatic laryngeal injury in appropriate patients.[24] The 9 patients with an etiology of autoimmune disease include the following: 3 patients with stenosis near or contacting the vocal folds, 2 patients with stenosis that appeared too long for CTR, and 1 patient with a previous CTR. Overall, patients with an etiology of trauma or autoimmune disease had decannulation rates of 90% and 89%, respectively.

Within the present institution, open surgical treatment of subglottic and tracheal stenosis had routinely been managed by open tracheal resection and re-anastomosis following the reports of Montgomery[25] and Grillo[26] in the 1960s and 1970s. Although this surgical approach resulted in a high success rate with a low rate of stenosis recurrence, limitations persisted in preserving laryngeal function as stenoses reached the level of the vocal folds. Along the same time period, initial experience with staged trough tracheoplasty was described by Friedman et al[27] and Bryce and Lawson.[28] From the potential for vocal fold preservation and avoidance of circumferential healing, the present institution began to apply LTP for select stenosis patients in the late 1980s and early 1990s.

Limitations of this study include those associated with a retrospective case series. A chart review may be limited by data reporting, but it is fortunate that we were able to ascertain desired characteristics for all patients. Follow-up time was not uniform across the cohort but was sufficiently long to obtain the relevant data in all patients.

Subglottic stenosis is a challenging disorder with multiple management options. The findings presented suggest that staged LTP and CTR both show excellent outcomes, although patient-specific anatomic features may guide the optimal surgical approach. The experience presented may serve as a basis for prospective study design, which would be necessary to further characterize and compare the advantages of each procedure.

Conclusion

The recommendations of a single surgical approach for subglottic stenosis are complex and must be tailored to each patient's pathology. Patient characteristics that may favor a choice of LTP include stenoses with close proximity to the vocal folds and stenotic segments approaching 6 cm. In patients with grade IV stenosis, LTP yields a lower decannulation rate than in patients with lower grade stenosis. Etiology of stenosis must also be a consideration when discussing surgical options. Further study is required to identify the optimal surgical approach in this challenging condition.

Declaration of Conflicting Interests

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References

1. Peña J, Cicero R, Marín J, Ramírez M, Cruz S, Navarro F. Laryngotracheal reconstruction in subglottic stenosis: an ancient problem still present. *Otolaryngol Head Neck Surg*. 2001;125:397-400.
2. Herrington HC, Weber SM, Andersen PE. Modern management of laryngotracheal stenosis. *Laryngoscope*. 2006;116(9):1553-1557.

3. Van den Boogert J, Hans Hoeve LJ, Struijs A, Hagenouw RRPM, Bogers AJJC. Single-stage surgical repair of benign laryngotracheal stenosis in adults. *Head Neck*. 2004;26:111-117.
4. Parida PK, Gupta AK. Management of laryngotracheal stenosis—our experience. *Indian J Otolaryngol Head Neck Surg*. 2009;61(4):306-312.
5. Lano CF, Duncavage JA, Reinisch L, Ossoff RH, Courey MS, Netterville JL. Laryngotracheal reconstruction in the adult: a ten year experience. *Ann Otol Rhinol Laryngol*. 1998;107:92-97.
6. Sisk JD, Schweinfurth JM. Cartilage graft laryngotracheoplasty for anterior subglottic stenoses. *Laryngoscope*. 2008;118(5):813-815.
7. Montgomery WW. Suprahyoid release for tracheal anastomosis. *Arch Otolaryngol*. 1974;99(4):255-260.
8. Grillo HC, Dignan EF, Miura T. Extensive resection and reconstruction of mediastinal trachea without prosthesis or graft: an anatomical study in man. *J Thorac Cardiovasc Surg*. 1964;48:741-749.
9. Lorenz RR. Adult laryngotracheal stenosis: etiology and surgical management. *Curr Opin Otolaryngol Head Neck Surg*. 2003;11:467-472.
10. Wester JL, Clayburgh DR, Stott WJ, Schindler JS, Andersen PE, Gross ND. Airway reconstruction in Wegener's granulomatosis-associated laryngotracheal stenosis. *Laryngoscope*. 2011;121(12):2566-2571.
11. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-383.
12. Myer CM, O'Connor DM, Cotton RT. Proposed grading system for subglottic stenosis based on endotracheal tube sizes. *Ann Otol Rhinol Laryngol*. 1994;103:319-323.
13. Pearson FG, Cooper JD, Nelems JM, Van Nostrand AW. Primary tracheal anastomosis after resection of the cricoid cartilage with preservation of recurrent laryngeal nerves. *J Thorac Cardiovasc Surg*. 1975;70:806-816.
14. Rea F, Callegaro D, Loy M, et al. Benign tracheal and laryngotracheal stenosis: surgical treatment and results. *Eur J Cardiothorac Surg*. 2002;22:352-356.
15. Wolf M, Shapira Y, Talmi YP, Novikov I, Kronenberg J, Yellin A. Laryngotracheal anastomosis: primary and revised procedures. *Laryngoscope*. 2001;111:622-627.
16. Rhee JS, Toohill RJ. Single-stage adult laryngotracheal reconstruction without stenting. *Laryngoscope*. 2001;111:765-768.
17. Thomé R, Thomé DC, Behlau M. The use of buccal mucosa graft at posterior cricoid splitting for subglottic stenosis repair. *Laryngoscope*. 2001;111:2191-2194.
18. Chen WX, Ruan YY, Cui PC, Sun YZ. Long-term results of the sternohyoid myocutaneous rotary door flap for laryngotracheal reconstruction. *Ann Otol Rhinol Laryngol*. 2002;111:93-95.
19. Negm H, Mosleh M, Fathy H. Circumferential tracheal resection with primary anastomosis for post-intubation tracheal stenosis: study of 24 cases. *Eur Arch Otorhinolaryngol*. 2013;270(10):2709-2717.
20. Laccourreye O, Brasnu D, Seckin S, Hans S, Biacabe B, Laccourreye H. Cricotracheal anastomosis for assisted ventilation-induced stenosis. *Arch Otolaryngol Head Neck Surg*. 1997;123:1074-1077.
21. Abbasidezfouli A, Akbarian E, Shadmehr MB, et al. The etiological factors of recurrence after tracheal resection and reconstruction in post-intubation stenosis. *Interact Cardiovasc Thorac Surg*. 2009;9(3):446-449.
22. Hartley BE, Cotton RT. Paediatric airway stenosis: laryngotracheal reconstruction or cricotracheal resection? *Clin Otolaryngol Allied Sci*. 2000;25(5):342-349.
23. Gallo A, Pagliuca G, Greco A, et al. Laryngotracheal stenosis treated with multiple surgeries: experience, results and prognostic factors in 70 patients. *Acta Otorhinolaryngol Ital*. 2012;32(3):182-188.
24. Grillo HC. Primary reconstruction of airway after resection of subglottic laryngeal and upper tracheal stenosis. *Ann Thorac Surg*. 1982;33:3-18.
25. Montgomery WW. Reconstruction of the cervical trachea. 1964. *Ann Otol Rhinol Laryngol*. 2004;113(1):5-15.
26. Grillo HC. Tracheal reconstruction. Indications and techniques. *Arch Otolaryngol*. 1972;96(1):31-39.
27. Friedman WH, Biller HF, Som ML. Repair of extended laryngotracheal stenosis. *Arch Otolaryngol*. 1975;101(3):152-156.
28. Bryce DP, Lawson VG. The "trough" method of laryngotracheal reconstruction. *Ann Otol Rhinol Laryngol*. 1967;76(4):793-803.