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# Predictors of Tracheostomy Decannulation in Adult Laryngotracheal Stenosis

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## Abstract

*Objective.* Predictors of tracheostomy decannulation in patients with laryngotracheal stenosis are not fully known, making prognosis difficult. The aim was to identify predictors of tracheostomy decannulation in adult patients with acquired stenosis of the larynx and/or trachea who were tracheostomy dependent.

*Study Design.* Case series.

*Setting.* Academic teaching hospital.

*Methods.* A total of 103 consecutive adult patients with laryngotracheal stenosis who were tracheostomy dependent and seen by the otolaryngology clinic from January 1, 2013, to August 2, 2018, were included. Exclusion criteria included age <18 years, history of laryngeal cancer or head and neck radiation, or history of laryngeal fracture. The primary outcome was the presence of tracheostomy at last follow-up. The patients' etiology of stenosis, comorbid conditions, and characteristics of the stenosis were analyzed to determine if there was a statistically significant relationship with decannulation.

*Results.* A total of 103 patients were included: 67% of patients were women and the average age was 53.5 years. Sixty-four patients (62%) were successfully decannulated. In multivariate analysis, patients who were successfully decannulated presented to the otolaryngology clinic earlier after tracheostomy was performed, were more likely to have been intubated due to trauma, and were less likely to have gastroesophageal reflux disease. In patients with subglottic or tracheal stenosis, those with granulation tissue without firm scar were more likely to be decannulated, and those who underwent rigid dilation were less likely to be decannulated.

*Conclusion.* Early evaluation by an otolaryngologist may increase the likelihood of tracheostomy decannulation in patients with laryngotracheal stenosis. Patient comorbidities may assist in predicting which patients will be successfully decannulated.

## Keywords

posterior glottic stenosis, subglottic stenosis, tracheostomy decannulation

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Laryngotracheal stenosis is a fixed obstruction of the upper airway, which can lead to difficulty with breathing and even death. Most commonly, it is iatrogenic in etiology. Other etiologies include traumatic, autoimmune, or idiopathic. Treatment options include endoscopic management, open resection, and tracheotomy. However, tracheotomy can also lead to stenosis of the airway as a result of cartilage fracture during the procedure itself or as a result of pressure exerted by the cuff or tip of the tracheostomy tube in the airway.[1,2]

The risk factors for development of laryngotracheal stenosis, the optimal management strategies, and the predictors of tracheostomy decannulation in patients with laryngotracheal stenosis are not fully known. Several factors have been associated with development of laryngotracheal stenosis in intubated patients, including female sex, obesity, diabetes, and gastroesophageal reflux disease (GERD).[3] The etiology of stenosis appears to affect the need for tracheostomy. In a single-institution study, 66% of patients with iatrogenic stenosis and 54% of patients with an autoimmune etiology of stenosis were tracheostomy dependent,[4] while a multi-institutional study found that only 3% of patients with idiopathic subglottic stenosis required a tracheostomy.[5] Additionally, patients with stenosis who are not treated with intralesional steroids appear to have a higher likelihood of tracheostomy dependence.[5] Risk factors for inability to decannulate tracheostomy include severity of stenosis and greater number of medical comorbidities.[4,6]

A variety of endoscopic treatment modalities are used in the management of laryngotracheal stenosis, including rigid

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dilation, balloon dilation, laser, steroid injection, and mitomycin C application. Multiple modalities are frequently used at the same time. It is not well established which, if any, interventions are associated with superior outcomes.[7] The aim of this study was to perform a retrospective chart review of patients with laryngotracheal stenosis at our institution who were tracheostomy dependent and to evaluate demographic characteristics, medical comorbidities, and characteristics of the airway stenosis and details of treatment to identify predictors of tracheostomy decannulation. Early intervention on acute inflammatory postintubation injuries has been demonstrated to result in a lower likelihood of needing multiple surgical interventions and requiring external laryngotracheal reconstruction.[8] As such, we hypothesized that patients would have a higher likelihood of tracheostomy decannulation if (1) their stenosis consisted primarily of granulation tissue rather than firm scar and (2) they presented to the otolaryngology clinic earlier after their tracheostomy was performed.

## Methods

This study was approved by the University of Maryland Institutional Review Board. Medical records were reviewed for adult patients presenting to the otolaryngology outpatient clinic with laryngeal and/or tracheal stenosis who were treated between January 1, 2013, and August 2, 2018, and who had already required a tracheostomy during their treatment course (n = 144). Patients <18 years of age, with a history of laryngeal cancer or head and neck radiation, or with a history of laryngeal fracture were excluded. Patients with insufficient medical record data regarding their comorbid conditions, etiology of stenosis, and treatment of stenosis were excluded. The remaining patients (n = 103) were included for analysis.

Patients' age, sex, body mass index (BMI), and medical comorbidities (cardiac disease, pulmonary disease, diabetes mellitus, GERD, hypothyroidism) were recorded. Medical comorbidities were identified from patients' self-reported medical history from the first hospital or clinic visit. The number of days from the tracheostomy to presentation to an otolaryngologist was recorded. Patients' tobacco-smoking status was recorded as current smokers, former smokers (≥10–pack year history), or nonsmokers (<10–pack year history). All patients who were current smokers received counseling on smoking cessation during clinic appointments. Etiology of stenosis (iatrogenic, traumatic, autoimmune) was recorded. None of our patients had idiopathic subglottic stenosis. We used the definition of iatrogenic and traumatic stenosis described by Gelbard et al,[4] in which iatrogenic stenosis occurred in patients intubated for medical comorbidities and traumatic stenosis occurred in patients intubated for a polytrauma involving multiple organ systems. The site of stenosis (glottic, subglottic, or tracheal), quality of stenosis (firm scar vs granulation tissue), details of treatment (open vs endoscopic; different endoscopic treatment modalities), tracheostomy decannulation, and requirement for revision tracheostomy were recorded.

The primary outcome was tracheostomy decannulation, defined as absence of tracheostomy at last follow-up visit.

### Statistical Analyses

Categorical variables were reported in frequency (percent), and continuous variables were summarized with mean and standard deviation. Univariate analysis was performed with the chi-square test for categorical variables and the *t* test for continuous variables. Variables that were statistically significant ($P < .05$) or near significant ($P < .2$) in univariate analysis were included in multivariate analysis via logistic regression. Logistic regression analysis was used to evaluate independent patient predictors on the outcome of interest: tracheostomy decannulation. These results are represented as odds ratios with 95% confidence intervals. This analysis was performed in R version 3.5.2 (https://www.r-project.org).

## Results

### Patient Characteristics

A total of 103 patients met inclusion criteria. The mean age was 53.5 years (range, 19-84) and 67% of patients were women. The average BMI was 31.7. Sixty-six patients (64%) had an iatrogenic etiology of stenosis, 34 (33%) a traumatic etiology, and 2 an autoimmune etiology. One patient had features of iatrogenic and autoimmune stenosis, and the etiology of stenosis is listed as ''unknown'' in **Table 1**. Sixty-four patients (62%) had their tracheostomy successfully decannulated. In univariate analysis, patients who were successfully decannulated had a lower average BMI (30.2 for patients decannulated vs 34.2 for those not decannulated, $P < .05$), were less likely to have underlying pulmonary disease (9% vs 31%, $P < .05$) or GERD (5% vs 26%, $P < .05$), were more likely to have been intubated because of a trauma (44% vs 15%, $P < .05$), and were less likely to have been intubated for an underlying medical comorbidity (56% vs 77%, $P < .05$).

The average time between the tracheostomy and presentation to an otolaryngologist was 209 days for those not decannulated versus 45 days for those who were ($P < .05$). As there was a high standard deviation in the time to presentation to otolaryngology (478 days for those not decannulated and 77 days for those who were decannulated), 15 patients were removed from this analysis per the cutoff for outliers (the third quartile + 1.5 times the interquartile range). After removal of outliers, the average time to presentation to the otolaryngology clinic was 100 days for those not decannulated versus 20 days for those who were decannulated ($P < .001$).

Patient characteristics that were statistically significant or near significant ($P < .2$) in univariate analysis were included in multivariate analysis. In multivariate analysis, traumatic etiology of stenosis, GERD, and time to presentation to otolaryngology had a statistically significant relationship with decannulation. Traumatic etiology of stenosis was positively associated with decannulation, with an odds ratio of 5.34. GERD and longer time to presentation to otolaryngology

**Table 1.** Patients Who Did and Did Not Undergo Successful Decannulation.

| | No. (%) or mean (95% CI) | | | |
|---|---|---|---|---|
| | Total (N = 103) | Not decannulated (n = 39) | Decannulated (n = 64) | *P* value[b] |
| Female sex | 69 (67) | 25 (64) | 44 (69) | .602 |
| Age, y | 53.5 (50.6-56.4) | 54.2 (50.0-58.4) | 53 (49.1-56.9) | .696[c] |
| Body mass index | 31.7 (30.2-33.2) | 34.2 (31.8-36.6) | 30.2 (28.3-32.1) | **.014**[c] |
| Current and former smokers | 35 (38; n = 93)[a] | 18 (49; n = 37)[a] | 17 (30; n = 56)[a] | .066 |
| Cardiac disease | 59 (57) | 24 (62) | 35 (54) | .429 |
| Pulmonary disease | 18 (17) | 12 (31) | 6 (9) | **.004** |
| Diabetes | 35 (34) | 17 (44) | 18 (28) | .098 |
| Gastroesophageal reflux disease | 13 (13) | 10 (26) | 3 (5) | **.002** |
| Hypothyroidism | 6 (6) | 4 (10) | 2 (3) | .138 |
| Percutaneous tracheostomy | 18 (21; n = 83)[a] | 3 (12; n = 26)[a] | 15 (26; n = 57)[a] | .153 |
| Etiology of stenosis | | | | |
| Iatrogenic | 66 (64) | 30 (77) | 36 (56) | **.032** |
| Trauma | 34 (33) | 6 (15) | 28 (44) | **.003** |
| Autoimmune | 2 (2) | 2 (5) | 0 (0) | |
| Unknown | 1 (1) | 1 (3) | 0 (0) | |
| Time to otolaryngology presentation, d[d] | 51 (30.9-71.1; n = 88)[a] | 100 (46.8-153; n = 27)[a] | 20 (15.2-24.8; n = 61)[a] | <**.001**[c] |

[a]For characteristics that were not recorded for all 103 patients, the extra number in parentheses represents the number of patients for which the variable was recorded.
[b]Decannulated versus not decannulated. Bold values represent $P < .05$. Comparisons are based on a chi-square test unless noted otherwise.
[c]Student *t* test.
[d]Outliers were removed.

**Table 2.** Multivariate Analysis of Patient Characteristics That Were Significant or Near Significant in Univariate Analysis.[a]

| | Odds ratio (95% CI) | *P* value[b] |
|---|---|---|
| Smoking | 0.357 (0.096-1.257) | .111 |
| Pulmonary disease | 0.434 (0.082-2.299) | .316 |
| Diabetes | 1.467 (0.357-6.932) | .607 |
| Gastroesophageal reflux disease | 0.055 (0.003-0.403) | **.015** |
| Traumatic etiology of stenosis | 5.339 (1.168-33.886) | **.046** |
| Percutaneous tracheostomy | 1.358 (0.242-10.971) | .743 |
| Hypothyroidism | 0.327 (0.009-6.770) | .480 |
| Body mass index | 0.953 (0.876-1.032) | .240 |
| Time to presentation to otolaryngology | 0.980 (0.958-0.993) | **.028** |

[a]Patient characteristics that were significant or near significant ($P < .2$) in univariate analysis were included in multivariate analysis per logistic regression. The odds ratio is for decannulation.
[b]Bold values represent $P < .05$.

were negatively associated with decannulation, with odds ratios of 0.06 and 0.98, respectively, meaning that for each additional day after tracheostomy prior to presentation to otolaryngology, the likelihood of tracheostomy decannulation declined by 2% (**Table 2**).

## *Surgical Interventions*

Patients underwent an average of 1.7 surgical procedures (range, 0-13). Twenty-three patients had posterior glottic stenosis without subglottic or tracheal stenosis, and 14 of these patients (61%) were successfully decannulated (**Figure 1**). Of the remaining patients who had subglottic and/or tracheal stenosis with or without concurrent posterior glottic stenosis, 50 of 80 (62.5%) were successfully decannulated. There were no statistically significant differences in the sites of stenosis between patients who were decannulated and patients who were not. Of the patients who were decannulated, 33 (51%) had 1 site of stenosis, as opposed to 19 (49%) who were not decannulated. This difference was not statistically significant. Forty-two patients had stenosis in which the subglottic or tracheal component of the stenosis consisted primarily of granulation tissue without mature scar. Excluding patients with isolated posterior glottic stenosis, 30 (70%) patients who were decannulated had subglottic/tracheal stenosis composed primarily of granulation tissue, as compared with 7 (24%) patients who were not decannulated ($P < .001$).

Of the patients with subglottic and/or tracheal stenosis with or without concurrent posterior glottic stenosis, 61 underwent an endoscopic intervention for the stenosis. Of these patients 40 (66%) were ultimately decannulated. Intralesional steroid injection was used in 56 of 61 (92%) patients with subglottic and/or tracheal stenosis and was the most commonly used treatment modality. Of the 61 patients, 36 with subglottic/tracheal stenosis had concurrent posterior glottic stenosis, while 25 patients had subglottic/tracheal stenosis only. Of the 25 patients with subglottic/tracheal stenosis only, 15 (60%) were able to be decannulated. Rigid dilation was used in 60% of the patients who were not

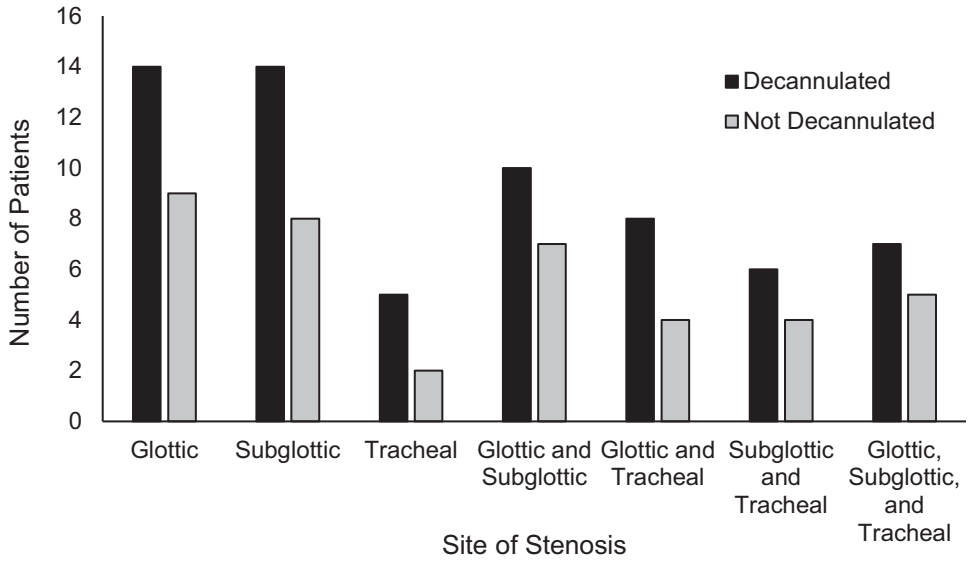


**Figure 1.** Number of patients with stenosis at each site. Black bars represent patients who did not undergo decannulation, and gray bars represent patients who did.

**Table 3.** Endoscopic Interventions in Patients With Stenosis of the Subglottis and/or Trachea and Without Concurrent Posterior Glottic Stenosis.[a]

| Intervention | Total (n = 25) | Not decannulated (n = 10) | Decannulated (n = 15) | *P* value[b] |
|---|---|---|---|---|
| Rigid dilation | 9 (36) | 6 (60) | 3 (20) | **.002** |
| Balloon dilation | 5 (20) | 2 (20) | 3 (20) | >.999 |
| Laser | 9 (36) | 3 (30) | 6 (40) | .617 |
| Airway stenting | 3 (12) | 2 (20) | 1 (7) | .340 |
| Intralesional steroid | 22 (88) | 9 (90) | 13 (87) | .823 |
| Mitomycin C | 3 (12) | 1 (10) | 2 (13) | .823 |
| Microdebrider | 10 (40) | 5 (50) | 5 (33) | .405 |

[a]Values represent No. (%) and were compared with a chi-square test.
[b]Not decannulated versus decannulated. Bold values represent $P < .05$.

decannulated, as opposed to 20% of the patients who were decannulated ($P < .05$). In patients with subglottic/tracheal stenosis only, the frequency of use of intralesional steroids, laser, microdebrider, mitomycin C, balloon dilation, and airway stenting did not differ between patients who were decannulated and those who were not (**Table 3**, **Figure 2**). When all 61 patients with subglottic/tracheal stenosis with or without concurrent posterior glottic stenosis were included, rigid dilation was also utilized in a higher percentage of patients who were not decannulated (43% vs 13%, $P < .05$); there were no statistically significant differences in the use of the other treatment modalities in patients who were and were not decannulated.

Three patients underwent open surgical intervention at our institution. Two patients underwent tracheal resection, and 1 underwent cricotracheal resection. One of the patients undergoing tracheal resection had an illicit drug overdose leading to respiratory failure requiring intubation and revision tracheostomy. The other 2 patients underwent successful open surgery. Tracheal resection was recommended for an additional patient, who did not follow up with us because of active alcohol abuse. This patient ultimately underwent a successful tracheal resection at another institution and was included in **Table 1** with the group of patients who were successfully decannulated.

Twenty patients did not undergo any surgery for their stenosis. Eleven of these patients were able to be decannulated. Seven patients who were decannulated without undergoing surgery had posterior glottic stenosis: 2 of these patients self-decannulated, and 5 had posterior glottic stenosis that was mild enough that they were able to be decannulated without intervention. The other 4 patients had subglottic stenosis consisting of granulation tissue that resolved with medical management.

### *Reasons for Inability to Decannulate Tracheostomy*

Nine patients did not undergo any surgery and were not decannulated. Four of these were determined not to be

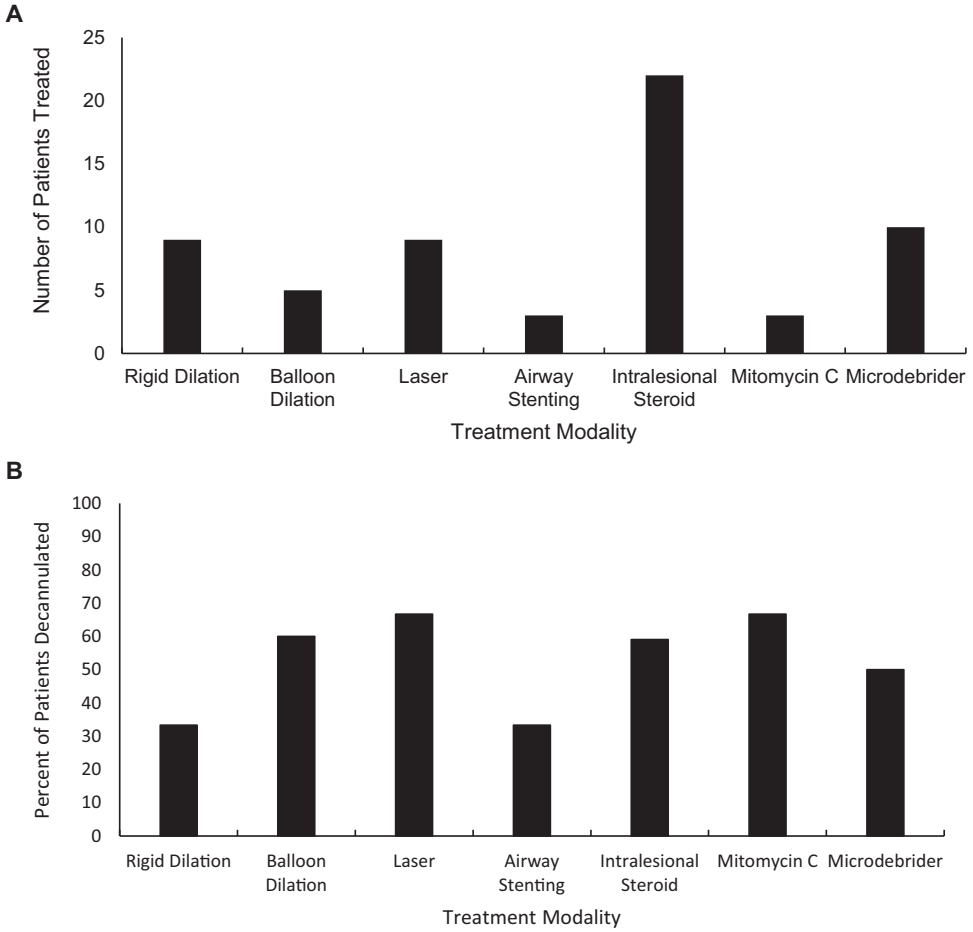


**Figure 2.** Endoscopic treatment modalities in patients with subglottic and/or tracheal stenosis without concurrent posterior glottic stenosis: (A) number of patients treated and (B) percentage of patients who underwent decannulation.

candidates for decannulation attributed to medical comorbidities; 3 did not follow up; and 2 declined surgery.

Seven patients with subglottic/tracheal stenosis composed primarily of granulation tissue were not able to be decannulated. Two were not decannulated due to poor neurologic status, 2 to pulmonary comorbidities, and 1 to morbid obesity and chronic obstructive pulmonary disease. Two did not follow up for evaluation for additional surgery.

The remaining 23 patients were not decannulated for various reasons. Seven patients were thought to be eligible for decannulation from an airway perspective but were not decannulated due to pulmonary comorbidities or poor neurologic status. Four patients were candidates for open surgery: 2 of these patients declined surgery and 2 may undergo surgery in the future. Four patients were determined not to be a candidate for open surgery because of medical comorbidities. Four patients had stenosis that was not amenable to open surgery. Two of these patients were evaluated at another institution with the same outcome. It was unclear from chart review why 3 patients were not able to be decannulated. One patient underwent open resection but required a revision tracheostomy, as discussed earlier.

## Discussion

Our overall rate of tracheostomy decannulation was 62%. In patients who underwent an endoscopic intervention and did not have isolated posterior glottic stenosis, the rate was 63%, which is equivalent to the 63% success rate of decannulation with endoscopic procedures in a systematic review by Lewis et al.[9] In our study, patients who were decannulated were more likely to have a traumatic etiology of their stenosis as defined by Gelbard et al,[4] meaning that they were intubated for a polytrauma involving multiple organ systems. We found that 82% of our patients with a traumatic etiology of stenosis were decannulated, as compared with 55% of patients with an iatrogenic etiology. Gelbard et al also found that patients with a traumatic etiology of stenosis were less likely to be tracheostomy dependent at last follow-up than patients with an iatrogenic etiology (33% vs 66%).[4] This finding may be related to the fact that patients with a traumatic etiology had fewer comorbidities. None of our patients had idiopathic subglottic stenosis. This may reflect the low rate of tracheostomy dependence in patients with idiopathic subglottic stenosis.[5]

Medical comorbidities such as obesity, diabetes, and GERD have been associated with development of laryngotracheal stenosis in intubated patients and with decannulation failure in laryngotracheal reconstruction.[10-12] In our case series, tracheostomy-dependent patients with laryngotracheal stenosis who were able to be decannulated had a lower average BMI and were less likely to have pulmonary disease or GERD than those who were not decannulated. Only GERD was significant in multivariate analysis. The role of GERD in laryngotracheal stenosis is not fully understood; however, it is thought that gastric acid, pepsin, and bile acids in refluxate can potentiate the development of stenosis in the setting of underlying laryngotracheal injury.[13,14] Blumin and Johnston found that 13 (59%) of 22 patients with laryngotracheal stenosis had pepsin present in their larynx/trachea, while none of the controls had any detectable pepsin on biopsy.[15] We classified patients as having GERD if they reported a medical history of GERD at the time of their first hospital admission or clinic visit. Given the retrospective nature of our study, we were not able to determine how the diagnosis of GERD was reached in our patient population, and we could not determine whether GERD was playing a causal role in the development of stenosis or if it was merely a correlation.

Tobacco smoking and diabetes mellitus are suspected to play a role in laryngotracheal stenosis through their effects on wound healing. Tobacco use causes vasoconstriction, mediated by nicotine, which could further reduce blood flow to tissue that is already vulnerable to ischemia.[16] Diabetes is known to cause microvascular injury and decreased angiogenesis, which could lead to laryngotracheal stenosis.[17] While this was not statistically significant, there was a trend toward decannulated patients being less likely to have diabetes ($P = .098$) or be current or former smokers ($P = .066$; **Table 1**). Of the patients who had a smoking history, 10 were current smokers, and the rest were former smokers with at least a 10–pack year history. All patients who were current smokers received smoking cessation counseling.

In patients with subglottic/tracheal stenosis consisting primarily of granulation tissue rather than mature scar, 83% were able to be decannulated. Patients who were decannulated were more likely to have stenosis consisting primarily of granulation tissue than those who were not decannulated (70% vs 24%, $P < .001$). Of the 7 patients with granulation tissue who were not decannulated, 5 had comorbidities that prevented decannulation, and 2 did not follow up for surgery. Similarly, Nouraei et al observed that earlier endoscopic intervention in the postintubation period may prevent granulation tissue from progressing into mature scar and may lead to fewer surgical interventions and prevent the need for laryngotracheal reconstruction.[8] This is consistent with our findings. Patients who were decannulated presented to our otolaryngology practice earlier on average than those who were not decannulated (20 vs 100 days posttracheostomy, $P < .05$), which may suggest that earlier intervention in these patients led to improved outcomes. Alternatively, it is possible that patients with more medical comorbidities required a longer period of time to recuperate from their acute illness prior to presentation to our department.

Patients in our case series underwent a variety of endoscopic interventions, with intralesional steroid injection being the most common (**Table 3**, **Figure 2**). In patients who underwent endoscopic intervention for subglottic/tracheal stenosis without concurrent posterior glottic stenosis, rigid dilation was used in a higher proportion of patients who were not decannulated. This was also true when we included patients with subglottic/tracheal stenosis with concurrent posterior glottic stenosis. It has been theorized that balloon dilation may be superior to rigid dilation because it allows radial force to be applied to a targeted area of stenosis, while rigid dilation may cause additional trauma to the airway through shear forces. There are few studies directly comparing rigid dilation and balloon dilation. Hseu et al did not find a difference in time to next dilation for rigid dilation versus balloon dilation.[7] We did not find any other statistically significant differences in decannulation outcomes with the different endoscopic interventions. Medical comorbidities were the most common reason why patients were unable to be decannulated. Only 4 patients had stenosis that was not amenable to surgical treatment.

Our findings are limited by the lack of randomization to the different interventions and the lack of a control group. Additional limitations of our study include that it was a retrospective study conducted at a single institution and the sample sizes for each site of stenosis were modest.

## Conclusion

In our case series of 103 patients with laryngotracheal stenosis with a tracheostomy, patients who were decannulated were less likely to have pulmonary disease or GERD and were more likely to have lower BMIs and a traumatic etiology of their stenosis in univariate analysis. Patients who were decannulated presented to otolaryngology at a shorter time interval after their tracheostomy. In multivariate analysis, GERD, traumatic etiology of stenosis, and length of time to presentation to otolaryngology were significant. Patients who were decannulated were more likely to have subglottic and/or tracheal stenosis consisting of granulation tissue. Rigid dilation was associated with a lower likelihood of tracheostomy decannulation in patients with subglottic/tracheal stenosis.

### Author Contributions

**Grace E. Snow**, study design, data analysis and interpretation, manuscript preparation and approval, responsibility for content; **Timothy Brandon Shaver**, data analysis and interpretation, manuscript preparation and approval, responsibility for content; **Taylor B. Teplitzky**, data analysis and interpretation, manuscript preparation and approval, responsibility for content; **Elizabeth Guardiani**, study design, data analysis and interpretation, manuscript preparation and approval, responsibility for content.

## Disclosures

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