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Surveillance Endoscopy After Tracheostomy Placement in Children: Findings and Interventions

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Objectives/Hypothesis: The Seattle Children's Hospital implemented the Trach Safe Initiative to improve airway safety in tracheostomy-dependent children (TDC). A key tenet of this initiative is surveillance endoscopy. The objectives of this study were to describe the prevalence of abnormal airway changes in TDC, identify risk factors for these changes, and describe the frequency of airway interventions.

Study Design: Retrospective case series.

Methods: This is a review of children 0 to 21 years old who underwent tracheostomy and surveillance endoscopy from February 1, 2014 to January 1, 2019. Descriptive statistics were used to report the prevalence of abnormal airway changes and interventions following tracheostomy. Pearson χ^2 tests and logistic regression were used to identify risk factors for the development of abnormal changes.

Results: There were 127 children identified. The median time from tracheostomy to initial surveillance endoscopy was 1.6 months (interquartile range = 1.3–2.4 months). At initial endoscopy, 86.6% of patients had at least one abnormal airway finding. The most common findings were subglottic edema/stenosis (57.3%), glottic edema (37.3%), and suprastomal granulation tissue (31.8%). Prematurity and a history of failed extubations were significantly associated with abnormal findings on endoscopy (odds ratio [OR] = 7.2, P = .01 and OR = 4.1, P = .03, respectively). Of those with abnormal findings, 32.7% underwent an intervention to improve airway patency and safety. The most common interventions performed were suprastomal granuloma excision (44.4%), steroid injection (22.2%), and balloon dilation of the glottis or subglottis (19.4%).

Conclusions: The prevalence of early abnormal airway changes in TDC is high, particularly in young children with a history of prematurity and failed extubation.

Key Words: Pediatric tracheostomy, tracheostomy, endoscopy, surveillance, airway obstruction.

Level of Evidence: 4

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INTRODUCTION

In the United States, approximately 4,500 to 5,000 pediatric tracheostomies are performed annually.[1] Indications for tracheostomy include congenital and acquired upper airway obstruction, as well as the need for prolonged mechanical ventilation due to pulmonary, neurological, or neuromuscular disease.[2,3] The reported overall complication rates range from 44% to 77%, whereas tracheostomy-specific mortality rates range from 0.7% to 3.6%.[4,5] Pediatric tracheostomies carry a greater risk of complications compared to adult patients, especially in children under the age of 2 years.[6,7] Furthermore, pediatric patients requiring tracheostomies are typically medically complex; therefore, complications such as accidental decannulation may be less well tolerated.

There is no standardized protocol for airway surveillance in pediatric tracheostomy patients. Some institutions perform routine endoscopic surveillance of patients following tracheostomy,[8] whereas others defer endoscopic evaluations to when patients exhibit symptoms of airway pathology. The official recommendation by the American Thoracic Society is to perform routine bronchoscopy every 6 to 12 months in children with tracheostomies, with the objectives of identifying and treating airway complications, evaluating the appropriateness of tracheostomy tube size, and to assess for decannulation readiness if clinically applicable.[9]

In 2014, Seattle Children's Hospital (SCH) established the Trach Safe Initiative. It is a quality-improvement initiative with the goal of improving the airway safety of tracheostomy-dependent children (TDC). The Trach Safe Initiative was the result of a multidisciplinary collaboration in response to an increase in unanticipated deaths in outpatient TDC from 2009 to 2013. An unanticipated death is one

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that is not related to progression of the underlying illness, and therefore may represent a preventable tracheostomy-related airway complication.

A key tenet of the Trach Safe Initiative is early surveillance endoscopy in children following tracheostomy placement. The first surveillance endoscopy is performed prior to the first hospital discharge, at approximately 1 to 3 months following tracheostomy placement. Subsequent endoscopies are performed after hospital discharge every 3 to 24 months based on the presence and severity of abnormal airway findings at the time of the most recent endoscopy, as well as the clinical trajectory of the patient.

The primary goal of surveillance endoscopy is to identify and treat airway abnormalities that compromise airway patency and safety. A second and equally important goal is to establish an emergency airway plan in the setting of tracheostomy tube occlusion or accidental decannulation. Specifically, at the time of surveillance endoscopy, the patient is assessed for their ability to be bag-mask ventilated with the tracheostomy tube occluded or removed. The modified Cormack-Lehane laryngoscopy grade[10] and appropriate endotracheal tube size is also documented as an estimation of the patient's ability to be orally intubated. Airway findings and the emergency airway plan are documented on the Trach Safe Airway Diagram, which is then distributed in three ways: it is scanned into the patient's medical record, a copy is provided to and reviewed with the patient's caregivers, and a copy is distributed to first responders in the area of the patient's residence.

The Trach Safe Initiative presents a unique opportunity to systematically study the airways of children who have undergone tracheostomy placement. The objectives of this study were to describe the prevalence of abnormal airway changes in TDC, to identify risk factors for these changes, and to assess the frequency of unplanned airway interventions. Our hypothesis is that TDC represent a high-risk population with a high rate of abnormal airway findings, with a large proportion of children requiring interventions to improve airway safety.

MATERIALS AND METHODS

This is a retrospective review of children who underwent tracheostomy placement and surveillance endoscopy as part of the Trach Safe Initiative from February 1, 2014 to January 1, 2019. Inclusion criteria were children under 21 years of age, with tracheostomy placed at SCH, and who underwent surveillance endoscopy including laryngoscopy and bronchoscopy. Initial surveillance endoscopy was performed during the hospitalization in which the tracheostomy was placed. Subsequent endoscopies occurred after discharge or during the same hospitalization as the tracheostomy placement in children with prolonged hospital stays. Children were excluded if they underwent tracheostomy placement at institutions other than SCH. The study protocol was approved by the SCH Institutional Review Board.

Data on demographic and clinical variables were collected. The operative report from each surveillance endoscopy was reviewed. Abnormal airway findings were recorded and included glottic edema, subglottic stenosis, suprastomal granulation tissue, and suprastomal collapse. The performance of unplanned airway interventions was also recorded. An unplanned airway intervention was defined as an intervention that was not anticipated prior to the surveillance endoscopy; however, an intraoperative decision was made to perform the intervention to increase the patency and safety of the airway. Such interventions included steroid injection and dilation to improve glottic and subglottic stenosis, suprastomal granulation tissue excision to facilitate bag-mask ventilation, and stomal revision in settings of stomal stenosis leading to difficult tracheostomy tube changes.

The primary outcome was the prevalence of abnormal airway findings in tracheostomy patients. Secondary outcomes were risk factors for abnormal airway findings and the frequency of unplanned airway interventions.

The prevalence of abnormal airway changes and the frequency of unplanned interventions are reported using descriptive statistics. Potential risk factors for (1) development of abnormal airway changes and (2) unplanned interventions were entered as predictors in separate univariate logistic regression models. Univariate analysis was chosen because the relationships between specific patient and clinical variables are not clearly established. To determine whether abnormal findings on endoscopy were associated with an increased probability of abnormal findings on subsequent endoscopy, prior abnormal findings were entered as predictors of subsequent abnormal findings into a generalized linear mixed model with covariance structure and random intercept. The same analysis was performed to determine whether unplanned interventions on endoscopy were associated with an increased probability of unplanned interventions on subsequent endoscopy. Analyses were conducted at the $\alpha = .05$ level of significance. Data analysis was performed using Stata version 12 (StataCorp, College Station, TX) and SAS version 9.4 (SAS Institute, Cary, NC).

TABLE I.
Demographic and Clinical Characteristics of the Study Population.

	No. of Patients
Median age at time of tracheostomy, mo (IQR)	5.6 (2.5–34.1)
Sex	
Male	74 (58.3%)
Female	53 (41.7%)
Ethnicity	
White	66 (51.9%)
Black	11 (8.7%)
Hispanic	20 (15.8%)
Asian	5 (3.9%)
Native Alaskan, Pacific Islander	7 (5.5%)
Mixed race or other	18 (14.2%)
Indication for tracheostomy	
Congenital upper airway obstruction	27 (21.3%)
Acquired upper airway obstruction*	20 (15.8%)
Neurological/neuromuscular disease	27 (21.3%)
Pulmonary insufficiency	53 (41.7%)
History of prematurity	71 (55.9%)
Ventilator dependence	81 (63.8%)
Intubation prior to tracheostomy	84 (69.3%)
If intubated, median length of intubation, wk (IQR)	7.6 (2.9–17.1)
History of failed extubation†	56 (44.8%)

*Acquired upper airway obstruction—failed extubation secondary to laryngeal or tracheal obstruction from prolonged or traumatic intubation.
†In children who were intubated.
IQR = interquartile range.

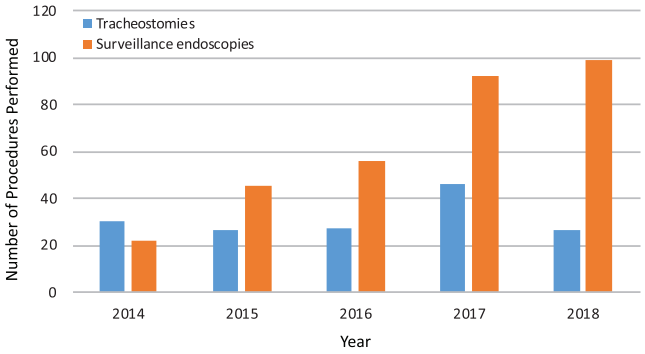

Fig. 1. Number of tracheostomies and surveillance endoscopies performed yearly from 2014 to 2018. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

RESULTS

One hundred twenty-seven patients met inclusion criteria, with a total of 314 surveillance endoscopies. The demographic and clinical characteristics of the patients are outlined in Table I. The average number of tracheostomies performed per year from 2014 to 2019 was 31 (standard deviation = 8.5). The number of surveillance endoscopies performed per year increased overtime, whereas the number of tracheostomies performed remained constant overall (Fig. 1). The median length of hospital admission after tracheostomy placement was 2.5 months (interquartile range [IQR] = 1.4–4.5 months). The median length of follow-up after discharge was 17.9 months (IQR = 8.2–34.6 months). Over the follow-up period, the median number of surveillance endoscopies performed per patient was two (IQR = 1–3). The median time from tracheostomy placement to the first surveillance endoscopy was 1.6 months (IQR = 1.25–2.4 months). For those with more than two endoscopies, the median intervals between the first and second, the second and third, and the third and fourth surveillance endoscopies were 6.6 months (IQR = 2.9–13.1 months), 5.7 months (IQR = 3.6–11.1 months), and 6.2 months (IQR = 3.5–14 months), respectively. Twenty-seven children underwent four or more surveillance endoscopies.

The number of patients undergoing surveillance endoscopy and the rate of abnormal findings and interventions are shown in Figure 2. A flowchart documenting the findings and intervention rates for the first two surveillance endoscopies are shown in Figure 3. There were no procedure-related complications in children undergoing surveillance endoscopy.

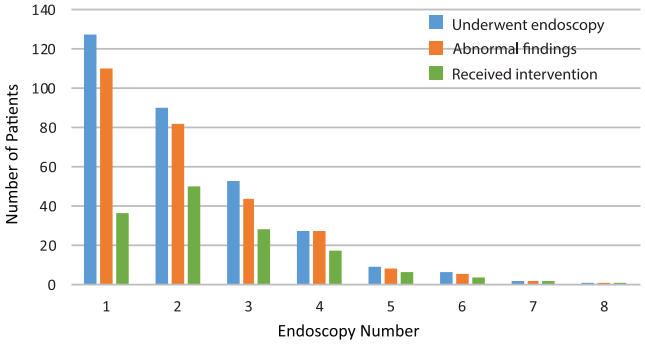

Fig. 2. The rate of abnormal findings and interventions in patients undergoing surveillance endoscopy. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

Abnormal Airway Findings

On initial endoscopy, 110 children (86.6%) had at least one abnormal airway finding (Fig. 4). Of these children, the most commonly observed findings were subglottic stenosis (57.3%), glottic edema (37.3%), and suprastomal granulation tissue (31.8%). Ninety children underwent a second surveillance endoscopy, with at least one abnormal finding noted in 82 children (91.1%). Of the 90 children with a second endoscopy, nine (10.0%) had abnormal findings that were not seen on the first surveillance endoscopy. A third surveillance endoscopy was performed in 53 children, with an abnormal finding rate of 83.0%; no abnormal findings were found in children who had normal exams on the previous two endoscopies.

The presence of an abnormal airway finding at the time of surveillance endoscopy is associated with a 90.9% (95% confidence interval [CI]: 83.2%-95.3%, $P = .03$) probability of an abnormal finding on subsequent endoscopy. Table II summarizes the probabilities of specific findings on any endoscopy based on findings from the previous endoscopy.

Prematurity and a history of failed extubations demonstrated increased odds for abnormal findings on initial surveillance endoscopy compared to children without a history of prematurity or failed extubations (odds ratio [OR] = 7.2, 95% CI: 1.6-33.1, $P = .01$ and OR = 4.1, 95% CI: 1.1-15.2, $P = .03$, respectively). Increased chronological age at the time of tracheostomy carried a decrease in the odds of abnormal findings. Specifically, with every 1-year increase in age, there was a 0.12 decrease in the odds of abnormal findings (95% CI: 0.04-0.19, $P = .003$). The duration of intubation prior to tracheostomy was not associated with an increased risk of abnormal airway findings (OR = 1.1, 95% CI: 0.98-1.23, $P = .11$). Tracheostomy indication and ventilator dependence were also not associated with abnormal findings (OR = 1.2, 95% CI: 0.80-1.86, $P = .3$ and OR = 2.2, 95% CI: 0.79-6.22, $P = .1$, respectively).

Prematurity, ventilator dependence, and increased length of intubation were significant risk factors for subglottic stenosis (OR = 2.96, 95% CI: 1.42-6.19, $P = .004$; OR = 2.41, 95% CI: 1.15-5.06, $P = .02$; and OR = 1.07, 95% CI: 1.01-1.13, $P = .02$, respectively). Children who received a tracheostomy for acquired upper airway obstruction were also more likely to exhibit findings of subglottic stenosis ($\chi^2[3] = 13.2$, $P = .004$). Increased age at the time of tracheostomy placement was associated with a decrease in the odds ratio of subglottic stenosis; specifically, every 1-year increase in age is associated with a 0.14 decrease in the odds of subglottic stenosis (95% CI: 0.05-0.21, $P = .002$).

Unplanned Interventions

Thirty-six (32.7%) children with abnormal findings underwent an unplanned airway intervention to improve airway patency and safety at the first surveillance endoscopy (Fig. 5). The most common interventions performed were suprastomal granuloma excision (44.4%), steroid injection (22.2%), and dilation of the glottis or subglottis (19.4%). Prematurity, history of failed extubations, chronological age at tracheostomy, length of intubation,

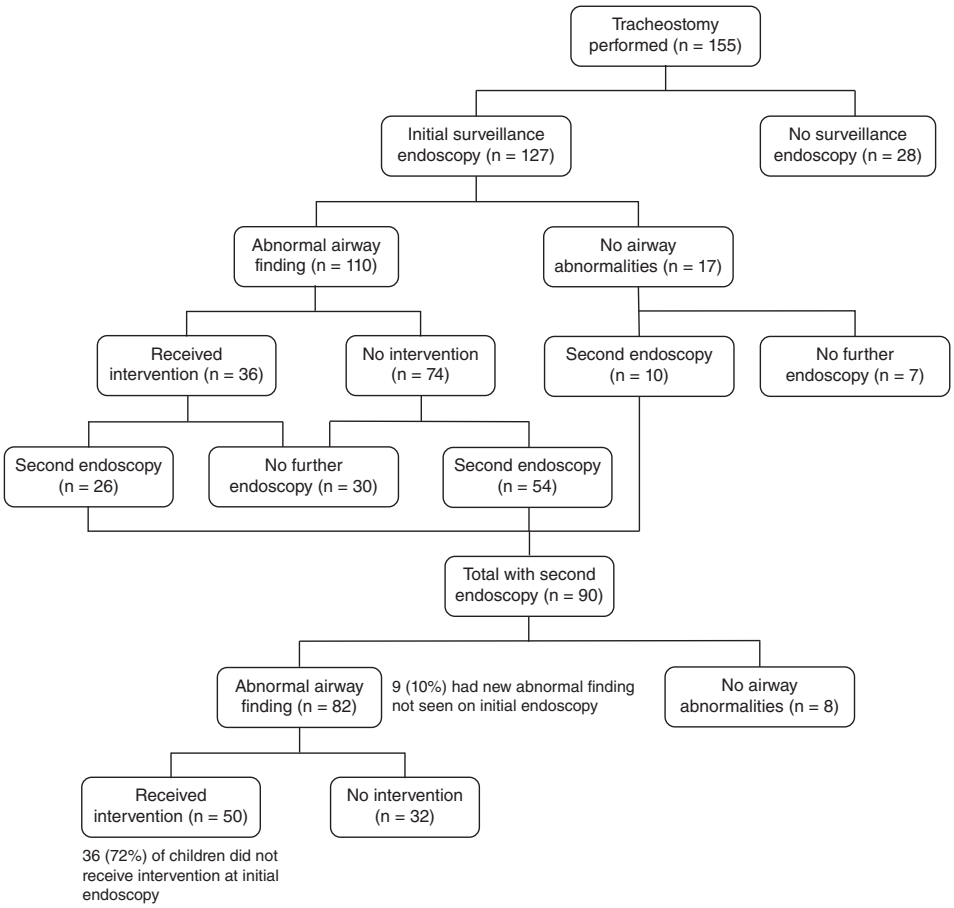

Fig. 3. Abnormal airway findings and unplanned interventions in patients undergoing the first and second surveillance endoscopies.

TABLE II.
Probability of Finding a Specific Abnormality Based on the Presence or Absence of the Abnormality on the Previous Endoscopy.

	Presence of Abnormality on the Previous Endoscopy		Absence of Abnormality on the Previous Endoscopy		
	Probability of Abnormality on Current Endoscopy	95% CI	Probability of Abnormality on Current Endoscopy	95% CI	*P* Value
Subglottic stenosis	80.3%	70.6-87.4	11.5%	5.0-24.1	<.001
Suprastomal granulation tissue	60.5%	47.2-72.3	35.9%	26.4-46.6	.005
Suprastomal collapse	50.6%	36.9-64.2	6.7%	2.9-14.5	<.001

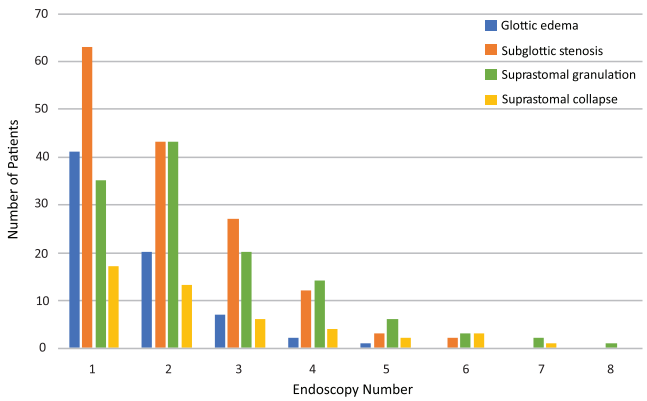

Fig. 4. Number of patients with abnormal airway findings on surveillance endoscopy. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

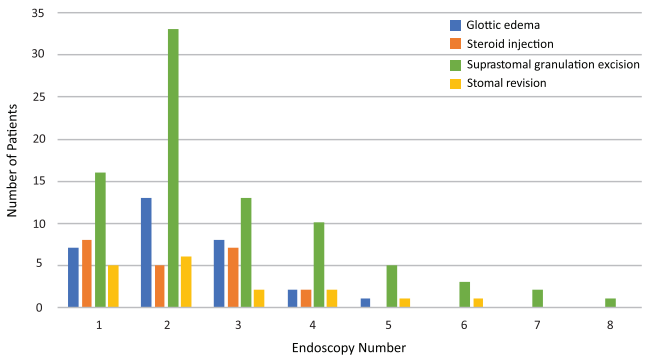

Fig. 5. Unplanned airway interventions on surveillance endoscopy in children with abnormal airway findings. [Color figure can be viewed in the online issue, which is available at www.laryngoscope.com.]

tracheostomy indication, and ventilator dependence were not associated with an increased risk of unplanned interventions at initial endoscopy. At the second endoscopy, 50 (61.0%) children with abnormal findings underwent an intervention. Of these children, 36 (72.0%) did not have an intervention at the first surveillance endoscopy. Fifty-three children had a third surveillance endoscopy, with 28 (63.6%) undergoing an intervention; four (14.3%) did not have an intervention at the first or second surveillance endoscopies. Undergoing an intervention was not predictive of undergoing additional interventions on subsequent endoscopy (OR = 1.0, 95% CI: 0.6-1.9, P = .93).

DISCUSSION

There was a high rate of abnormal airway findings in our cohort, supporting our hypothesis that children with tracheostomies represent a high-risk population for airway abnormalities. The most common findings among all endoscopies were, in descending order, subglottic stenosis, suprastomal granulation tissue, glottic edema, and suprastomal collapse. Over the first 3 surveillance endoscopies, 83% to 91% of children exhibited airway abnormalities. This is higher than that reported in the literature. A recent published study by Gergin et al. of surveillance endoscopy in children with tracheostomies found an airway lesion rate of 55.1%.[11] A potential explanation for this difference is the timing of the patient populations. The series by Gergin et al. examined children with tracheostomies performed between 1984 and 2015,[11] whereas our study examines a more contemporary cohort, with tracheostomies performed between 2014 to 2018. We speculate that the overall increase in observed airway abnormalities in our cohort compared to prior series is related to the trend of increasing survivorship of critically ill children.

Risk factors for airway abnormalities include prematurity and a history of failed extubation. Risk factors for subglottic stenosis were prolonged duration of intubation, prematurity, and ventilator dependence. Children with tracheostomy placement for laryngeal or tracheal obstruction secondary to prolonged or traumatic intubation were also at increased risk for subsequent findings of subglottic stenosis. In selecting patients for surveillance, children with the above-mentioned clinical characteristics represent a higher-risk population who may most benefit from early endoscopy. Increased chronological age at the time of tracheostomy was associated with a decrease in the odds of developing abnormal airway findings; however, given an OR of 0.12, this may not represent a clinically significant finding. In a previous study that investigated the presence of airway abnormalities in pediatric tracheostomy patients, there was no significant association between age at time of tracheostomy and the development of abnormal airway findings.[11]

A large proportion of our patients received unplanned interventions at the time of surveillance endoscopy, as they had airway abnormalities that were felt to compromise airway safety. Specifically, the rate of interventions at the first and second surveillance endoscopies were 32.7% and 61.0%, respectively. This is similar to the rate reported in the series by Richter et al., whereby interventions were performed in 58% of endoscopies.[8] In our population, at the second endoscopy, the majority (72%) of children receiving interventions did not receive an intervention at the initial endoscopy. This underlines the importance of scheduled endoscopic follow-up in children with abnormal findings at the first surveillance endoscopy, even if an intervention was not initially indicated, as airway abnormalities may evolve overtime to become clinically significant. This is particularly relevant given the ongoing controversy regarding the role of clinical symptoms as an indication for endoscopy in TDC. Gergin et al. showed an association between clinical symptoms and airway lesions; however, there was no association between preprocedural symptoms and the need for airway intervention during surveillance endoscopy.[11]

Currently, no guidelines exist for the timing of surveillance endoscopy. In our cohort, the median time to the first surveillance endoscopy was 1.6 months. Seventy percent of patients had a second endoscopy, with the median interval from the first endoscopy being 6.6 months. This timeframe is shorter than other published series, where the first follow-up endoscopy has been reported 12 to 14 months after tracheostomy placement.[8,11] The earlier timeframe reflects the goal of the Trach Safe Initiative, which is to systematically evaluate the airway prior to the first hospital discharge after tracheostomy placement, to create an emergency airway plan, and to intervene, if necessary, to maximize the safety of the airway prior to discharge. The timing of subsequent exams ranges from 3 to 24 months, depending on the status of the airway at the time of the initial endoscopy. Given the high rate of abnormal findings and interventions, the timing of earlier surveillance of the Trach Safe Initiative may be appropriate as it is capturing a large number of children with potentially unsafe airways should their tracheostomy tube become obstructed or dislodged.

The selection of patients for repeat surveillance endoscopy after the initial endoscopy is also not well-established. In our cohort, the presence of an abnormal airway finding carried a 90.9% probability of a subsequent abnormal finding. Furthermore, at the second endoscopy, only 10% of children had abnormal findings in the setting of a normal initial endoscopy. At the third endoscopy, there were no new presentations of abnormal findings. This suggests that if a child has two normal surveillance endoscopic exams, decisions regarding further endoscopic surveillance may be based to a larger degree on other factors such as airway symptoms or decannulation planning.

Three limitations should be considered for this study. First, the operative reports from surveillance endoscopies performed as part of the Trach Safe Initiative were not standardized. As a result, there is loss of granularity in the data. Although most surgeons employed the Cotton-Meyer grading system to report subglottic stenosis,[12] some reported the presence or absence of subglottic stenosis without formally sizing the airway. The nature of the stenosis (i.e., edematous stenosis vs. firm stenosis) was also not consistently reported. Furthermore, distal pathologies such as tracheomalacia and bronchomalacia were not routinely assessed and documented; therefore, the focus of this article was on actionable otolaryngologic findings at the laryngeal and proximal tracheal levels. Improvement of the Trach Safe Initiative would include standardized reporting of all aspects of the procedure as well as the findings. Second, early surveillance endoscopy adds cost to patient care as well as potential morbidity; there

is risk to patients in undergoing general anesthesia, especially in the setting of multiple comorbidities.[13] In our study, no endoscopy-associated complications were seen; therefore, improving airway safety with potential avoidance of unanticipated mortality may outweigh the cost and low risk of surveillance endoscopy. Future areas of work include specifically examining the cost-effectiveness of surveillance endoscopy. Additional work is also underway to evaluate the impact of the Trach Safe Initiative on unanticipated mortality in TDC. Finally, there is a risk of selection bias due to the retrospective nature of this study; the high rate of abnormal findings and interventions may reflect the selection of patients with more severe airway abnormalities or those who exhibited greater airway symptoms.

CONCLUSION

Surveillance endoscopy detects high rates of airway abnormalities. A significant proportion of our cohort were found to have abnormalities that posed risks to airway safety, with subsequent performance of interventions aimed at reducing these risks. Identifying and intervening on obstructive airway pathologies may lead to improved airway safety in tracheostomy-dependent children.

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