ORIGINAL RESEARCH

Retrospective Analysis of Factors Leading to Pediatric Tracheostomy Decannulation Failure

A Single-Institution Experience

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Abstract

Rationale: There is a lack of evidence regarding factors associated with failure of tracheostomy decannulation.

Objectives: We aimed to identify characteristics of pediatric patients who fail a tracheostomy decannulation challenge

Methods: A retrospective review was performed on all patients who had a decannulation challenge at a tertiary care center from June 2006 to October 2013. Tracheostomy decannulation failure was defined as reinsertion of the tracheostomy tube within 6 months of the challenge. Data on demographics, indications for tracheostomy, home mechanical ventilation, and comorbidities were collected. Data were also collected on specific airway endoscopic findings during the predecannulation bronchoscopy and airway surgical procedures before decannulation. We attempted to predict the decannulation outcome by analyzing associations.

Measurements and Main Results: 147 of 189 (77.8%) patients were successfully decannulated on the first attempt. Tracheostomy performed due to chronic respiratory failure decreased odds for decannulation failure (odds ratio = 0.34, 95% confidence interval = 0.15–0.77). Genetic abnormalities (45%) and feeding dysfunction (93%) were increased in the population of patients failing their first attempt. The presence of one comorbidity increased the odds of failure by 68% (odds ratio = 1.68, 95% confidence interval = 1.23–2.29). Decannulation pursuit based on parental expectation of success, rather than medically determined readiness, was associated with a higher chance of failure ($P = 0.01$).

Conclusions: Our study highlights the role of genetic abnormalities, feeding dysfunction, and multiple comorbidities in patients who fail decannulation. Our findings also demonstrate that the outcome of decannulation may be predicted by the indication for tracheostomy. Patients who had tracheostomy placed for chronic respiratory support had a higher likelihood of success. Absence of a surgically treatable airway obstruction abnormality on the predecannulation bronchoscopy increased the chances of success.

Keywords: tracheostomy decannulation; decannulation failure; comorbidities tracheostomy; airway obstruction; polysomnography

(Received in original form June 22, 2016; accepted in final form September 25, 2016)

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Author Contributions: A.B. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis, including and especially any adverse effects, and assumes full responsibility for the integrity of the submission as a whole, from inception to published article; A.B., A.I.C., and A.D. made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, writing of the manuscript, revised the manuscript critically for important intellectual content, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; S.D.D., V.L.A., J.E.S., H.E.J., and D.C.G. made substantial contributions to interpretation of data, revised the manuscript critically for important intellectual content, provided final approval of the version to be published, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Ann Am Thorac Soc Vol 14, No 1, pp 70–75, Jan 2017

Originally Published in Press as DOI: 10.1513/AnnalsATS.201607-553OC on October 21, 2016
Internet address: www.atsjournals.org

Tracheostomy tube placement is performed to establish secure airway access. Prolongation of tracheostomy beyond medical need predisposes to speech problems, increased airway infections, higher medical costs, limitation of participation in school, and sudden death from mucous plugging (1–3). Surveys of caregivers of a child with a tracheostomy highlight the disruption of social interactions within and outside the family due to the child's condition (4). However, there is a paucity of validated objective data on determining readiness for decannulation (5).

A recent retrospective analysis (6) reported a shorter time to decannulation in children with laryngotracheal/maxillofacial trauma compared with children who received tracheostomy for cardiopulmonary or neurological reasons. This finding implies that decannulation outcome may be related to underlying etiologic factors, which has been confirmed in several other studies (1, 7–9).

Although several groups have evaluated decannulation success rates and tracheostomy outcomes based on indication of placement, there is no evidence evaluating the impact of age, tracheostomy duration, and presence of chronic respiratory failure on decannulation outcomes. Furthermore, the effect of comorbidities on decannulation outcomes is lacking in the literature. In preparation for decannulation, bronchoscopy evaluation is the standard of care. There is a lack of evidence on bronchoscopy findings that may influence decannulation outcome. Through this retrospective analysis, our aim was to identify the factors determining decannulation failure in pediatric patients.

We hypothesized that pediatric patients who fail a decannulation challenge have distinct characteristics, including the etiologies leading to tracheostomy and number of comorbidities. We also hypothesized that these patients have distinct findings on their predecannulation airway endoscopic evaluation that predict outcome. Some of the results of this study have been previously reported in the form of an abstract at the American Thoracic Society Conference, May 17th, 2015, in Denver, Colorado (10).

Methods

A retrospective review was conducted on patients with a tracheostomy evaluated for decannulation at our institution from June 2006 to October 2013. Our study was approved by the Indiana University School of Medicine (Indianapolis, IN) Institutional Review Board (protocol 1306011701). Patients were identified through billing codes that pertain to decannulation (*International Classification of Diseases, Ninth Revision* [ICD-9] billing code chronic respiratory failure [CRF]: 518.83 and nap polysomnogram/overnight polysomnogram [NPSG/OPSG]: 95,808/95,810). Inclusion criteria included patients under 18 years of age who had a decannulation attempt in the Riley Pediatric Sleep Laboratory (Indianapolis, IN). This population has been described in our previous publication (11).

Tracheostomy Decannulation Protocol

The Riley decannulation protocol has been previously described in detail (12). In brief, this protocol involves bronchoscopy for patients deemed eligible by the physician's clinical assessment. Once bronchoscopy findings reveal that the patient's airway is free of significant airway obstruction, a decannulation challenge is conducted in the sleep laboratory. The ostomy is covered by an occlusive dressing and respiratory parameters are measured awake and asleep during the day and overnight by polysomnography (PSG). The patient undergoes recannulation if the study reveals significant airway obstruction (apnea–hypopnea index $>$ 10 events/h), hypoventilation (end tidal carbon-dioxide [ET_{CO_2}] above 45 mm Hg for 20% of total sleep time), respiratory distress, or prolonged oxygen desaturation. The protocol does not involve downsizing of a tracheostomy tube or capping trials of the tracheostomy before attempted decannulation or the possibility of decannulation to noninvasive ventilation.

Decannulation Failure

Decannulation failure was defined as reinsertion of the tracheostomy tube during the decannulation challenge or within 6 months of decannulation. For patients with more than one failed attempt at decannulation, we collected data only for the first attempt.

Data Collection

For each patient, the following data were collected from the medical record: demographics; diagnoses leading to tracheostomy (dynamic airway collapse, lower airway structural abnormalities, obstructive apnea on PSG, craniofacial anomalies, chronic respiratory failure requiring prolonged respiratory support, and neuromuscular disorders); age at time of insertion of tracheostomy and time of attempted decannulation; need for home mechanical ventilation; and duration of home mechanical ventilation before decannulation. We also collected data on comorbidities, categorized as: genetic abnormalities; neurological abnormalities (presence of any of the following: hydrocephalus requiring placement of ventriculoperitoneal shunt; myelomeningocele; seizure disorder); cardiac abnormalities (congenital cyanotic heart disease); pulmonary hypertension requiring pharmacotherapy and oromotor incoordination, leading to feeding dysfunction necessitating gastrostomy tube placement.

Data on type of airway evaluation (flexible or rigid bronchoscopy) before the decannulation attempt, and time interval from airway evaluation until decannulation were collected. Data were also collected on specific airway endoscopic findings during the predecannulation bronchoscopy, (laryngomalacia, pharyngomalacia, tracheomalacia, or any other observed dynamic airway collapse, adenoid hypertrophy, tonsillar hypertrophy, airway stenosis, suprastomal or tracheal granuloma), number of airway surgical procedures before decannulation and interval duration from last surgical corrective intervention.

We compared the patients' characteristics, airway evaluation findings, and airway surgical procedures in patients who failed decannulation to those who were successfully decannulated during their first attempt, to predict decannulation outcome by analyzing associations.

Statistical Analysis

Fisher's exact test for categorical variables and Student's *t* test or Wilcoxon nonparametric test for continuous variables, depending on the data distribution, was used for analysis. Results are reported as median (range) for continuous variables and frequency (%) for categorical variables. To determine the magnitude in odds for a successful first decannulation attempt, logistic regression models were used to analyze predetermined predictor variables.

A proportional odds model was used to determine association of number of comorbidities on decannulation success. Due to the large number of comparisons, we adjusted the α level using a Bonferroni correction, with the number of outcomes in each section used as the adjustment value. Fisher's exact test was used to analyze role of corrective surgery on decannulation outcome. The significance level for statistical association was a *P* value less than 0.5.

All analytic assumptions were verified and all statistical tests were performed using SAS v9.4 (SAS Institute, Cary, NC).

Results

Between June 2006 and October 2013, we identified 189 patients who were evaluated for decannulation. To our knowledge, no patient had undergone decannulation in our hospital outside of this protocol. A total of 42 failed at their first attempt, which led to a decannulation failure rate of 22.2%. Of the 42 patients, 36 failed decannulation challenge immediately, whereas 6 patients were recannulated within 6 months. A lower median gestational age was noted to increase the chance for successful decannulation (Table 1). A total of 20 decannulation attempts was associated with high parental expectation for a decannulation trial, despite clinical concerns that the patient was not ready for decannulation. Of these, 11 (55%) failed the first decannulation attempt (Table 1). Premature attempt at decannulation was associated with a higher chance of failure ($P = 0.01$).

A comparison of comorbidities in patients based on their first decannulation outcome was performed (Table 2). For each indication and comorbidity, we have presented the likelihood of success versus failure as well as the odds ratio. Feeding dysfunction was the only one to remain significant after Bonferroni correction. A greater number of comorbidities decreased the odds of a successful first decannulation attempt. The presence of one comorbidity increased the odds of failure by 68% (odds ratio = 1.68, 95% confidence interval = 1.23–2.29). The presence of each additional comorbidity increased the odds of failure exponentially.

Almost all patients had flexible or rigid bronchoscopy performed within 1 month of their decannulation attempt. In patients with congenital cyanotic heart disease, 1 patient had extrinsic vascular compression, 1 had subglottic hemangioma, 17 had dynamic airway abnormality, and 5 had trachea-esophageal fistula. In the entire study population, presence of laryngomalacia, tracheomalacia, subglottic stenosis, tonsillar hypertrophy, and adenoidal hypertrophy were associated with a higher risk of first decannulation failure. Corrective surgical intervention for those with laryngomalacia (three underwent surgery vs. seven without surgery, $P = 0.5$), subglottic stenosis (eight underwent surgery vs. six without surgery, $P = 1.0$), granulation tissue (8 underwent surgery vs. 21 without surgery, $P = 0.4$), adenoidal (8 underwent surgery vs. 16 without surgery, $P = 1.0$), and tonsillar hypertrophy (five underwent surgery vs. six without surgery, $P = 1.0$), seen on predecannulation bronchoscopy, did not improve decannulation outcome. Absence of airway abnormalities in the predecannulation bronchoscopy had a higher chance of successful first decannulation attempt (Table 3).

Both groups (patients who passed and patients who failed their first decannulation attempt) had a comparable number of airway procedures performed before the first decannulation attempt (66.7 vs. 74%, $P = 0.43$). Adenoidectomy was the most common procedure performed in both the groups.

Discussion

Our study highlights the role of comorbidities in those who fail decannulation attempts. Presence of genetic abnormalities and oromotor incoordination leading to feeding dysfunction was associated with an increased failure rate. Our study also demonstrates that decannulation outcomes may be predicted based on the indication for initial tracheostomy. Patients who had a tracheostomy placed due to airway obstruction in the presence

Table 1. Baseline characteristics of all patients (n = 189)

Characteristics	Patients Who Failed First Decannulation Attempt (*n = 42*)	Patients Who Passed First Decannulation Attempt (*n = 147*)	Odds Ratio (95% CI) for Decannulation Failure	*P* Value
Female sex*	21 (50%)	55 (37%)	1.67 (0.84–3.33) (vs. male)	0.16
Median gestational age, wk†	36 (24–39)	34 (22–42)	1.08 (1.01–1.14)	0.05
Median age at tracheostomy, mo†	3 (0–184)	4 (0–206)	1.00 (0.99–1.01)	0.50
Median age at first decannulation attempt, mo†	37 (9–192)	32 (8–250)	1.00 (0.99–1.01)	0.78
Median duration of tracheostomy, mo†	29 (6–67)	25 (0–130)	0.99 (0.98–1.01)	0.86
Number of patients discharged on home mechanical ventilation after tracheostomy*	19 (45%)	60 (42%)	1.14 (0.57–2.27)	0.73
Median duration of home mechanical ventilation, mo†	20 (9–52)	16 (4–84)	1.02 (0.98–1.06)	0.07
Decannulation pursuit based on parental expectations of success*	11 (27%)	9 (6%)	5.26 (2.04–14.29)	0.01

Definition of abbreviation: CI = confidence interval.
Odds ratios and 95% CIs are from logistic regression models. *P* values are based on Fisher's exact test.
*Percentages for categorical variables.
†Median (minimum–maximum) for continuous variables.

Table 2. Indication and comorbidities in patients with decannulation attempt (n = 189)

	Total No. of Patients with Indication or Comorbidity	Patients with the Indication or Comorbidity Who Failed First Decannulation [*n (%)*]	Patients with the Indication or Comorbidity Who Passed First Decannulation [*n (%)*]	Likelihood of Success Compared to Failure of Decannulation Challenge for Patient with the Indication or Comorbidity	Odds Ratio (95% CI) for Decannulation Failure with and without that Indication/ Comorbidity	*P* Value
Indications						
Dynamic airway collapse*	76	22 (29)	54 (71)	2.5	1.89 (0.94–3.85)	0.08
Lower airway structural abnormalities*	61	14 (23)	47 (77)	3.4	1.06 (0.51–2.22)	0.85
Obstructive apnea on PSG*	32	10 (31)	22 (69)	2.2	1.79 (0.76–4.17)	0.24
Craniofacial anomalies*	26	10 (38)	16 (62)	1.6	2.56 (1.06–6.25)	0.04
Chronic respiratory failure requiring prolonged respiratory support*	74	9 (12)	65 (87)	7.3	0.34 (0.15–0.77)	0.01
Neuromuscular disorder*	20	6 (30)	14 (70)	2.3	1.59 (0.57–4.35)	0.39
Comorbidities						
Seizures*	27	9 (33)	18 (67)	2.0	1.96 (0.81–4.76)	0.14
Hydrocephalus with ventriculoperitoneal shunt placement*	16	5 (31)	11 (68)	2.2	1.67 (0.55–5.00)	0.37
Myelomeningocele*	7	4 (57)	3 (43)	0.8	5.00 (1.09–25.00)	0.04
Congenital cyanotic heart disease*	30	9 (30)	21 (70)	2.3	1.64 (0.68–3.85)	0.34
Genetic abnormalities*	56	19 (34)	37 (66)	1.9	1.89 (1.03–3.85)	0.03
Pulmonary hypertension*	35	7 (20)	28 (80)	4.0	0.85 (0.34–2.13)	0.82
Oromotor incoordination leading to feeding dysfunction*	142	39 (27)	103 (73)	2.7	5.56 (1.64–20.00)	0.01

Definition of abbreviations: CI = confidence interval; PSG = polysomnography.
Odds ratios and 95% CIs are from logistic regression models. *P* values are from Fisher's exact test for categorical variables.
*Percentages for categorical variables.

of craniofacial anomalies had a decreased rate of successful decannulation, whereas patients who had tracheostomy placed primarily for chronic respiratory support rather than airway obstruction had higher rates of successful decannulation.

Our results highlight the importance of airway evaluation before decannulation. Presence of subglottic stenosis, granulation tissue, or adenotonsillar hypertrophy decreased the chances for successful decannulation, even after surgical correction, whereas finding no surgically treatable airway obstruction abnormality on the predecannulation bronchoscopy increased the chances of success.

The median gestational age was lower in patients who were successfully decannulated during their first attempt. This implies that prematurity, by itself, may not be associated with a higher chance of failed decannulation. A total of 65 of 147 patients (44%) who passed their first decannulation attempt had a tracheostomy placed to provide prolonged respiratory support for chronic respiratory failure. Of these 65 patients, 45 (69%) were born prematurely (gestational age <37 wk). Our data, therefore, suggest that tracheotomy primarily for home mechanical ventilation in premature infants does not increase the risk for decannulation failure. This information may be important to share when counseling families of prematurely born patients with bronchopulmonary dysplasia requiring prolonged respiratory support. This observation is also consistent with our earlier study, showing that almost 60% of infants with severe bronchopulmonary dysplasia were likely to be successfully decannulated (11).

Almost 42% of our patients were treated with home mechanical ventilation. The duration of home mechanical ventilation in patients who required tracheostomy due to prolonged respiratory support did not seem to correlate with a worse outcome for decannulation. This supports current evidence that most children survive, or are weaned off, home mechanical ventilation (13).

Funamura and coworkers (6) reported that only 20.8% of patients who received tracheostomy for cardiopulmonary reasons had a successful decannulation. This difference may be due to variances in comorbidities between our patient populations or differences in the decannulation protocol. The current literature does not distinguish between the outcomes of decannulation in patients who received a tracheostomy primarily for airway abnormalities separately from those who received tracheostomy mainly for prolonged ventilator support. Our observations are thus difficult to compare with the existing literature.

In our study, the median duration of tracheostomy in patients who were successfully decannulated was 25 months. Our results are consistent with results reported by de Trey and colleagues (8), in which 70% of the patients were less than 1 year of age at the time of tracheostomy placement and were 28 months of age at the time of decannulation.

Of the 26 patients with craniofacial anomalies, 10 (38%) underwent successful decannulation. Of the 76 patients with dynamic airway collapse, 54 (71%) were successfully decannulated. These observations are higher than previously reported (6), where 16.7% of patients with craniofacial anomalies and 36.4%

Table 3. Airway evaluation findings analyzed based on decannulation outcomes

Bronchoscopic Findings	Type of Bronchoscopy	Patients Who Failed First Decannulation Attempt (*n = 42; Flexible, 21, Rigid, 21*)	Patients Who Passed First Decannulation Attempt (*n = 131; Flexible, 52, Rigid, 79*)	Odds Ratio (95% CI) for Decannulation Failure	*P* Value
Laryngomalacia*	Flexible	3 (14.3)	1 (1.9)	8.33 (0.83–100)	0.07
	Rigid	3 (14.3)	3 (3.8)	4.17 (0.79–25.00)	0.09
Pharyngomalacia*	Flexible	2 (9.5)	1 (1.9)	5.26 (0.46–50.00)	0.18
	Rigid	0 (0)	0 (0)	N/A	
Tracheomalacia*	Flexible	9 (42.9)	11 (21.2)	2.78 (0.93–8.33)	0.06
	Rigid	1 (4.8)	2 (2.5)	1.92 (0.17–20.00)	0.60
Dynamic collapse, unspecified*	Flexible	2 (9.5)	2 (3.9)	2.63 (0.35–20.00)	0.35
	Rigid	2 (9.5)	0 (0)	>99 (<0.01 to >99)	0.98
Subglottic stenosis*	Flexible	0 (0)	0 (0)	N/A	
	Rigid	7 (33.3)	6 (7.6)	6.25 (1.79–20.00)	**0.01**
Granulation tissue*	Flexible	6 (28.6)	7 (13.5)	2.56 (0.75–9.09)	0.13
	Rigid	10 (47.6)	6 (7.6)	11.11 (3.33–33.33)	**<0.01**
Tonsillar hypertrophy*	Flexible	3 (14.3)	4 (7.7)	2.00 (0.41–10.00)	0.39
	Rigid	3 (14.3)	1 (1.3)	12.50 (1.28–100)	0.03
Adenoidal hypertrophy*	Flexible	7 (33.3)	12 (23.1)	1.67 (0.55–5.00)	0.37
	Rigid	4 (19.1)	1 (1.3)	20.00 (1.28–100)	**0.01**
Any abnormality*	Flexible	18 (85.7)	24 (46.2)	7.14 (1.82–25.00)	**<0.01**
	Rigid	15 (71.4)	15 (19.0)	11.11 (3.57–33.33)	**<0.01**
	Overall (both flexible and rigid)	33 (78.6)	40 (27.2)	10.00 (4.35–20.00)	**<0.01**
No abnormality*	Flexible	3 (14.3)	27 (51.9)	0.15 (0.04–0.59)	**0.01**
	Rigid	6 (28.6)	60 (76.0)	0.13 (0.04–0.37)	**0.01**

Definition of abbreviations: CI = confidence interval; N/A = not applicable.
Odds ratios and 95% CIs are from logistic regression models. *P* values are from Fisher's exact test.
*Percentages for categorical variables. Values in bold typeface signify statistical significance ($P < 0.05$).

of patients with upper airway obstruction were successfully decannulated. This difference may be due to a different decannulation protocol, different age of the population, or differences in the number of airway interventions performed before the decannulation attempt.

Genetic malformations and oromotor incoordination leading to feeding dysfunction were associated with a higher risk of failed decannulation. These findings may imply that those with these difficulties had poor coordination of upper airway musculature, with an inability to adequately maintain airway patency without the tracheostomy. This may also reflect parenchymal disease due to recurrent episodes of microaspiration. Further studies to confirm this hypothesis are needed. Patients who failed their first decannulation attempt had a greater number of comorbidities than those who passed. Each additional comorbidity increases the chances of decannulation failure exponentially, which may suggest that it is the number as well as the nature of the comorbidity that contributes to decannulation failure.

Caregivers report a disruption of social interactions within and outside the family due to the presence of tracheostomy (4). This may lead to a sense of urgency from the caregiver to decannulate the patient, even if the child may not be medically ready. Decannulation pursuit based primarily on parental expectation of success, rather than medically determined readiness, was associated with a higher chance of failure in our study.

Although statistical significance was not achieved, there was a trend toward persistent airway dynamic collapse, particularly laryngomalacia and tracheomalacia, in patients who failed decannulation. This observation is consistent with those of a previous study (6). In our study, tracheomalacia was more commonly identified during flexible bronchoscopy.

The incidence of airway granulation tissue in patients with tracheostomy ranges from 72 to 80% (14, 15). In our study, only 29 of 173 patients (16.7%) were found to have airway granulation tissue in their predecannulation bronchoscopy. This lower prevalence may be due to removal of granulation tissue during prior surveillance airway evaluations. In a recent a survey of 75 members of the American Society of Pediatric Otolaryngology, wide practice variation in the management of suprastomal granulation tissue in pediatric patients with tracheostomies was observed (16). Rosenfeld and Stool (14) reported that management of granulation tissue by either excision or observation did not change the likelihood of detecting new granulation during a subsequent bronchoscopy. In our study, of the 29 patients noted to have granulation tissue on bronchoscopy, only 8 had an excision performed. Excision of granulation tissue was not associated with a greater incidence of decannulation success. However, presence of granulation tissue, regardless of surgical intervention, was associated

with a greater chance of decannulation failure.

A total of 136 (72%) had airway-corrective surgery performed before their first decannulation attempt in our study, which is higher than the 43% reported by Tantinikorn and colleagues (17). In our study, all patients, regardless of the outcome of the decannulation attempt, had a median of one surgical procedure performed before their decannulation attempt. In the study by Funamura and coworkers (6), patients with upper airway obstruction had three to four minor procedures before decannulation, which is higher than in our study. However, their study did not show increased likelihood of decannulation success with more airway procedures, which is consistent with our study. The current literature shows a higher decannulation success rate (85–95%) after laryngotracheoplasty or laryngotracheal reconstruction compared with our study (50%), where eight patients underwent laryngotracheal reconstruction. This result is limited by the small sample size (n = 8); however, it may also have been influenced by the presence of other comorbidities, including oromotor incoordination.

Limitations

The primary weaknesses of our study are its retrospective nature and the heterogeneous patient population with various diagnoses. However, this heterogeneous patient population is the nature of those requiring tracheostomy. At our institution, these patients are seen by pediatric pulmonologists or otolaryngologists (or both) based on individual patient health needs. Decisions about decannulation are based on the clinical discretion of the pulmonologist or otolaryngologist, which influences the timing and outcome of decannulation.

Due to the retrospective nature of our study, we were unable to characterize and get more objective evaluations of the indications for tracheostomy and associated comorbidities. Particularly, a more objective evaluation of oromotor incoordination leading to feeding dysfunction is required, as it may be a surrogate for poor handling of secretions, and can be a global predictor of failure associated with neurological impairment and upper airway hypotonia.

Another limitation of our study was that the findings on bronchoscopy, including the degree of lumen compromise, were based on the subjective assessment of the bronchoscopist. There may have been interobserver variability based on the experience and biases of the bronchoscopists. A prospective study with consistent grading of degree of airway obstruction will be extremely useful.

Finally, this is the experience of a single center, and practices may vary between different centers. Evaluation by PSG may not be the standard of care in other institutions, which may alter the decannulation success rate. The salient features of our protocol are: (*1*) all patients undergo PSG; (*2*) no patient is a candidate for decannulation to noninvasive ventilation; (*3*) no one undergoes downsizing of the tube with assessment before decannulation; and (*4*) no one undergoes capping trials. This study is based on our center's approach, and is a pilot initiative to gain a better understanding of this patient population.

Conclusions

Safe decannulation of children requiring tracheotomy is a difficult clinical decision with an element of risk. Hasty decannulation without adequately addressing comorbidities can result in adverse outcomes. Identifying those at increased risk for failure will improve the care these patients receive and set up realistic expectation for their caregivers. Future multicenter, prospective studies are needed to identify the population at increased risk for decannulation failure. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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