Extubation Readiness Practices and Barriers to Extubation in Pediatric Subjects

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BACKGROUND: Invasive mechanical ventilation is a lifesaving intervention that is associated with short- and long-term morbidities. Extubation readiness protocols aim to decrease extubation failure rates and simultaneously shorten the duration of invasive ventilation. This study sought to analyze extubation readiness practices at one institution and identify barriers to extubation in pediatric patients who have passed an extubation readiness test (ERT). METHODS: We performed a retrospective chart review of all pediatric subjects admitted between April 2017 and March 2018, and who were on mechanical ventilation. Exclusion criteria were cardiac ICU admission, tracheostomy, chronic ventilator support, limited resuscitation status, and death before extubation attempt. Data with regard to the method of ERT and reasons for delaying extubation were collected. RESULTS: There were 427 subjects included in the analysis with 69% having had an ERT before extubation. Of those, 39% were extubated per our daily spontaneous breathing trial (DSBT) protocol, and the DSBT failed in 30% but they had passed a subsequent pressure support and CPAP trial on the same day. The most common reasons for failing the DSBT were a lack of spontaneous breathing (30% [75/252]), being intubated < 24 h (24% [60/252]), breathing frequency outside the target range (22% [55/252]), and not meeting tidal volume goal (14% [34/252]). The most common documented reasons for delaying extubation despite passing DSBT were planned procedure (29% [26/90]), neurologic status (23% [21/90]), and no leak around the endotracheal tube (18% [16/90]). The median time between passing ERT and extubation was 7 h (interquartile range, 5–10). CONCLUSIONS: In our institution, there was variation in extubation readiness practices that could lead to a significant delay in liberation from invasive ventilation. Adjustment of our DSBT to tolerate a higher work of breathing, such as higher breathing frequencies and lower tidal volumes, and incorporating sedation scoring into the protocol could be made without significantly affecting extubation failure rates. *Key words: Airway extubation; extubation failure; ventilator weaning; intensive care units; pediatric*. [Respir Care 0;0(0):1–●. © 0 Daedalus Enterprises]

Introduction

Invasive mechanical ventilation is a lifesaving intervention that is commonly used in pediatric ICUs.[1,2] Pediatric critical care providers have recognized the risks associated with invasive ventilation, such as ventilator-associated pneumonia, ventilator-induced lung injury, ventilator-induced diaphragmatic dysfunction, and exposure to seda-

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tives and narcotics.[3-7] To minimize these risks and the risks associated with extubation failure, a systematic approach to evaluate a patient's ability to independently maintain adequate gas exchange without excessive respiratory effort can help pediatric critical care providers liberate patients earlier from invasive ventilation.

Extubation failure in the pediatric ICU ranges from 5% to 15% and can lead to significant morbidity and mortality.[8-10] Factors correlated with an increased risk of extubation failure include a longer duration of sedative use, longer duration of invasive ventilation, younger age, higher complexity of medical conditions, and diaphragmatic dysfunction.[5,6,11-13] These factors are often used by clinicians to predict the pre-extubation risk of extubation failure, which can affect the timing of extubation.[14] The most common reported cause of extubation failure in pediatric patients is upper-airway obstruction, with other causes that include respiratory insufficiency, muscular weakness, cardiac dysfunction, and neurologic impairment.[8,13,15] Upper-airway obstruction is usually secondary to glottic and subglottic edema from the resultant inflammation that occurs from airway trauma during intubation or irritation from the endotracheal tube during invasive ventilation.[16] As such, pediatric critical care providers may use nebulized racemic epinephrine, nebulized or intravenous steroids, high-flow nasal cannula, and heliox to avoid re-intubation.[17]

To mitigate these complications, published pediatric extubation readiness protocols focus on 4 elements: (1) frequent screening for eligibility to undergo a spontaneous breathing trial; (2) a spontaneous breathing trial that tests a patient's ability to maintain adequate minute ventilation and gas exchange; (3) evaluation of nonpulmonary factors that can affect extubation success (eg, hemodynamic status, pain, and sedation level), upper-airway control (eg, cough and gag reflexes), fluid status, and evaluation of leak pressure around the endotracheal tube; and (4) planning for respiratory support after extubation.[18-21] Although there are few published protocols, there currently are no standardized guidelines with regard to the best method to incorporate these elements into extubation protocols in the pediatric population, which can lead to wide variation in practice and delays in liberation from invasive ventilation.

The aims of this study were to describe extubation readiness practices in pediatric patients and identify barriers to extubation in subjects who have passed an extubation readiness test (ERT). We hypothesized that there is a variation in methods used to evaluate patients' readiness to be liberated from invasive ventilation in a single-center pediatric ICU based on pre-extubation risk factors for extubation failure, such as age, initial severity of illness, and duration of invasive ventilation,[14] and that this variation in practice can lead to significant delays in extubation.

QUICK LOOK

Current knowledge

Invasive mechanical ventilation is associated with numerous complications, so pediatric critical care providers commonly implement protocolized testing to provide earlier liberation from invasive mechanical ventilation. Currently, there are no guidelines for pediatric ventilator liberation; this leads to variation in extubation practices and delays in extubation.

What this paper contributes to our knowledge

This paper identifies common barriers to extubation such as not passing an extubation readiness test, planned procedure, neurologic status, and absence of air leak. Changes that could be incorporated into clinicians' home institution protocols include tolerating a higher work of breathing, incorporating sedation scoring, and implementing respiratory therapist-driven extubation rounds to facilitate earlier extubation.

Methods

In this retrospective cohort study, we included all children on mechanical ventilation < 18 y old who were admitted to the Riley Hospital for Children pediatric ICU between April 2017 and March 2018, and who were extubated. Riley Hospital is a quaternary-care children's hospital with ~2,500 pediatric ICU admission per year. Patients admitted to the cardiac ICU, patients who required a tracheostomy or chronic ventilator support, patients with limited resuscitation status, and patients who died without an extubation attempt were excluded. Patient demographics and clinical characteristics were obtained from Virtual PICU Systems (Los Angeles, California). Data with regard to which method of ERT and reasons for delaying extubation until the next calendar day despite passing an ERT were collected. Data were extracted from electronic medical records (Cerner, Kansas City, Missouri) and input into the RedCap database (Vanderbilt University, Nashville, Tennessee). The study was approved by the Indiana University Institutional Review Board.

ERT

Our daily spontaneous breathing trial (DSBT) is described in detail in our previous publication.[18] In summary, the subjects were screened daily at ~4:00 AM by bedside respiratory therapists to evaluate if they met the following criteria: no planned procedure; hemodynamically stable; no recent increase in vasoactive drips;

spontaneously breathing; no recent increase in ventilator settings; $F_{IO_2} < 0.5$, PEEP ≤ 6 cm H_2O, and oxygen saturation $\geq 92\%$; and peak inspiratory pressure ≤ 25 cm H_2O when using a tidal volume of 6–8 mL/kg in a volume-targeted mode or when achieving a tidal volume $\geq$ 6–8 mL/kg for peak inspiratory pressure set to ≤ 25 cm H_2O while using a pressure-targeted mode. If criteria were met, then PEEP would be reduced to 5 cm H_2O and F_{IO_2} to 0.4 for 5–10 min. If the subject passed this preparation phase, then a pressure support (PS) CPAP trial was performed at a PS of 8 cm H_2O and CPAP of 5 cm H_2O for 2 h. If the subject did not pass the DSBT PS/CPAP trial, the reason for trial failure was documented by the respiratory therapist in electronic medical records and the attending physician on service could do a subsequent PS/CPAP trial later that day after optimizations in sedation or fluid status were made. The PS values used for the subsequent trial varied based on physician judgment and ranged from 5 to 10 cm H_2O, with CPAP ranging from 5 to 6 cm H_2O.

Definitions

Extubation failure was defined as re-intubation within 48 h after the first extubation attempt. Extubating according to our DSBT protocol included all subjects extubated after passing both the preparation phase and a 2-h PS/CPAP trial of 8/5 cm H_2O for 2 h. Extubating "off protocol" was defined as extubating subjects who either did not receive any form of ERT or had failed any phase of the DSBT protocol but passed a subsequent PS/CPAP trial on the same calendar day.

Statistical Analysis

Data were exported from the RedCap database and then analyzed by using SAS v9.4 (SAS Institute, Cary, North Carolina). The duration of invasive mechanical ventilation was divided into 4 categories: <24 h, 1–7 d, 8–14 d, and >14 d. Continuous variables were reported as medians with 25th, 75th interquartile range (IQR), and categorical variables were reported as frequencies and percentages. The Kruskal-Wallis test was used for continuous variables, and the chi-square test or the Fisher exact test was used for categorical variables, as appropriate. Multivariate analyses were performed by using variables that were significant at $P < .20$ in the bivariate models as well as any demographic and clinical variables deemed relevant. All statistical analyses were made by considering a significance level of $P < .05$.

Results

Between April 2017 and March 2018, there were 705 patients admitted to our pediatric ICU who required invasive ventilation. A total of 278 patients were excluded: 231 had a tracheostomy or were on chronic ventilator support, 35 patients had limited code status, and 12 patients died without an extubation attempt. The remaining 427 patients who met inclusion criteria had a median age of 40 months (IQR 9–134). Respiratory etiology was the most common primary illness category (38.6% [165/427]), followed by injury and/or poisoning (19.0% [81/427]), and neurologic etiology (14.5% [62/427]). Subject demographics and clinical characteristics are summarized in Table 1.

ERT Method

Before extubation, 69.3% of the subjects (296/427) had an ERT; with 39.4% of the subjects (168/427) extubated after passing a DSBT and 30.0% (128/427) extubated after failing a DSBT but passing a subsequent PS/CPAP trial on the same day (Fig. 1). No ERT was done before extubation in 29.0% of the subjects (124/427), and 1.6% of extubations (7/427) were unplanned. The subjects who did not receive any ERT were older; had a lower PRISM (pediatric risk of mortality score) III score; and had been admitted to the pediatric ICU for an injury, poisoning, or neurologic etiology, or after surgery (Table 1). Of the subjects intubated < 24 h, 57.6% (80/139) were extubated without a formal ERT, whereas, 63.6% (35/55) and 70.6% (12/17) of the subjects intubated for 8–14 d and >14 d, respectively, were extubated according to our DSBT protocol (Table 2).

The reasons for extubating subjects off our DSBT pro-tocol are summarized in Figure 2. Of the subjects who were extubated "off protocol," a lack of spontaneous breathing (29.8% [75/252]), intubation < 24 h (23.8% [60/252]), breathing frequency outside the target range (21.8% [55/252]), and peak inspiration pressure or tidal volume goal not met (13.5% [34/252]) were the most common documented reasons. Reasons for extubating off protocol could fall into >1 category, and the subjects had between 1 and 4 documented reasons, with a median of 1 (IQR 1–2).

Barriers to Extubation

Reasons for delaying extubation despite passing a DSBT are summarized in Figure 3. The most common reasons were a planned procedure (28.9% [26/90]), neurologic status (23.3% [21/90]), and no leak around the endotracheal tube (17.8% [16/90]). Reasons for delaying extubation could fall into >1 category. The subjects had between 1 and 3 documented reasons, with a median of 1 (IQR 1–2). On the day of extubation, the median time between passing an ERT (DSBT or PS/CPAP) and extubation was 7 h (IQR 5–10), regardless of the duration of invasive ventilation (Table 2).

Table 1. Subject Demographics and Clinical Characteristics by Extubation Readiness Test Method

Variable	All Subjects ($N = 427$)	DSBT ($n = 168$)	PS/CPAP ($n = 128$)	No ERT ($n = 124$)	Unplanned Extubation ($n = 7$)	*P*
Age, median (IQR) mo	40 (9–134)	3.5 (6–94)	58.5 (10–145.5)	65 (15.5–163)	37 (4–188)	.02
Age categories, *n* (%)						.058
0–12 mo	123 (28.8)	57 (33.9)	35 (27.3)	29 (23.4)	2 (28.6)	
1–5 y	116 (27.2)	53 (31.6)	29 (22.7)	32 (25.8)	2 (28.6)	
6–11 y	80 (18.7)	31 (18.5)	26 (20.3)	23 (18.6)	0 (0)	
>11 y	108 (25.3)	27 (16.1)	38 (29.7)	40 (32.3)	3 (42.9)	
Girls, *n* (%)	192 (45.0)	73 (43.5)	56 (43.8)	61 (49.2)	2 (28.6)	.60
Race/ethnicity, *n* (%)						.40
White	314 (73.5)	119 (70.8)	95 (74.2)	95 (76.6)	5 (71.4)	
African American	75 (17.6)	29 (17.3)	23 (18.0)	22 (17.7)	1 (14.3)	
Hispanic	22 (5.2)	14 (8.3)	6 (4.7)	2 (1.6)	0 (0)	
Other	16 (3.8)	6 (3.6)	4 (3.1)	5 (4.0)	1 (14.3)	
PRISM III score, median (IQR)	3 (0–7)	4 (0–8)	3.5 (0–7)	2 (0–5)	5 (3–10)	.009
Primary illness category, *n* (%)						.005
Respiratory	165 (38.6)	77 (45.8)	48 (37.5)	38 (30.7)	2 (28.6)	
Injury and/or poisoning	81 (19.0)	25 (14.9)	22 (17.8)	33 (26.6)	1 (14.3)	
Neurologic	62 (14.5)	16 (9.5)	16 (12.5)	28 (22.6)	2 (28.6)	
Infectious	48 (11.2)	25 (14.9)	16 (12.5)	5 (4.0)	2 (28.6)	
Hematology and/or oncology	28 (6.6)	11 (6.6)	10 (7.8)	7 (5.7)	0 (0)	
Other	43 (10.1)	14 (8.3)	16 (12.5)	13 (1.5)	0 (0)	
Postoperative status, *n* (%)	117 (27.4)	35 (20.8)	40 (31.3)	42 (33.9)	0 (0)	.02
Trauma status, *n* (%)	55 (12.9)	16 (9.5)	20 (15.6)	19 (15.3)	0 (0)	.24
Trisomy 21, *n* (%)	7 (1.6)	2 (1.2)	2 (1.6)	3 (2.4)	0 (0)	.85
Bronchopulmonary dysplasia, *n* (%)	16 (3.8)	6 (3.6)	6 (4.7)	4 (3.2)	0 (0)	.87
Cerebral palsy, *n* (%)	21 (4.9)	6 (3.6)	7 (5.5)	6 (4.8)	2 (28.6)	.09

DSBT = daily spontaneous breathing trial
PS = pressure support
ERT = extubation readiness test
IQR = interquartile range (25th-75th)
PRISM = pediatric risk of mortality score

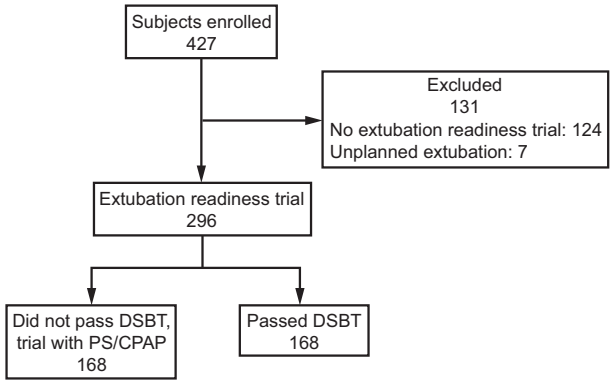

Fig. 1. Flow chart. DSBT = daily spontaneous breathing trial; PS = pressure support.

Extubation Outcomes

The extubation failure rate for the total cohort was 4.9% (21/427). Extubation failure rates were 8.9% (15/168) for those who passed a DSBT, 3.1% (4/128) for those who failed a DSBT but passed a subsequent PS/CPAP trial, 0/124 for those who had no ERT, and 28.6% (2/7) for those who had an unplanned extubation ($P < .001$) (Table 3). Multivariate analysis demonstrated that a respiratory etiol-ogy was associated with higher odds of extubation failure (odds ratio [OR] 8.96, 95% CI 2.49–32.27; $P < .001$) (Table 4). DSBT as a method of ERT did not increase the odds of extubation failure when compared with PS/CPAP (OR 0.33, 95% CI 0.10–1.12), no ERT, or unplanned extubation (OR 7.10, 95% CI 0.56–4.77); $P = .37$ (Table 4).

Noninvasive ventilation was used as an initial respiratory support modality after extubation in 5.4% of the subjects (23/427) for the whole cohort, with noninvasive ventilation accounting for 6.0% of the DSBT group (10/168), 4.7% of the PS/CPAP group (6/128), 5.7% of the group that did not receive ERT (7/124), and 0% of the unplanned extubation group (0/7) ($P < .001$) (Table 3). High-flow nasal cannula was used as an initial respiratory support modality in 30.9% of the subjects for the whole cohort (132/427), with high-flow nasal cannula accounting for 40.5% of the DSBT group (68/168), 33.6% of the PS/CPAP group (43/128), 13.7% of the group that did not receive ERT (17/124), and

Table 2. Extubation Readiness Testing Pactices Per iIvasive Mechanical Ventilation Duration

Variable	All Subjects ($N = 427$)	Invasive Ventilation				P
		< 24 h ($n = 139$)	1–7 d ($n = 216$)	8–14 d ($n = 55$)	>14 d ($n = 17$)	
ERT method						<.001
DSBT	168 (39.3)	16 (11.5)	105 (48.6)	35 (63.6)	12 (70.6)	
PS/CPAP	128 (30.0)	41 (29.5)	68 (31.5)	16 (29.1)	3 (17.7)	
No ERT	124 (29.0)	80 (57.6)	38 (17.6)	4 (7.3)	2 (11.8)	
Unplanned extubation	7 (1.6)	2 (1.4)	5 (2.3)	0 (0)	0 (0)	
No. of passed DSBTs done before extubation, median (IQR) [range]	1 (1–1) [1–8]	1 (1–1) [1–1]	1 (1–1) [1–6]	1 (1–2) [1–3]	1 (1–4) [1–8]	<.001
Time between passing ERT and extubation, median (IQR) h	7 (5–10)	7 (5–10)	7 (5–10)	8 (6–10)	7 (5–11)	.79

DSBT = daily spontaneous breathing trial
ERT = extubation readiness test
PS = pressure support

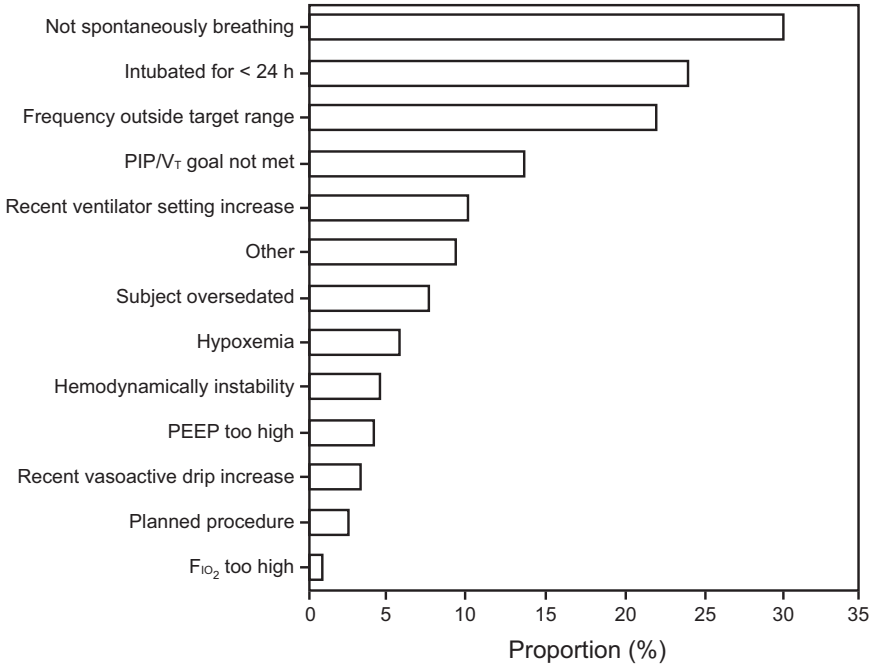

Fig. 2. Reasons for extubating "off protocol".

57.1% of the unplanned extubation group (4/7) ($P < .001$) (Table 3).

Discussion

Pediatric critical care providers lack evidence-based clinical practice guidelines for ERT compared with their adult counterparts.[22,23] Therefore, it is important to continuously scrutinize extubation readiness practices and to look for further refinements to decrease both the extubation failure rates as well as the duration of invasive ventilation. This study showed that there is variation in extubation readiness practices and helped illuminate barriers to extubating patients at our institution by providing areas where efforts should be focused to further optimize our protocol.

In ideal protocolized care, all patients would be extubated per the same ERT protocol and that protocol would be flexible enough to allow for calculated deviations. A lack of spontaneous breathing was the most common reason for extubating "off protocol." This was mostly likely related to oversedation but could also be due to the neurologic status in patients with status epilepticus or new neurologic injury; these are the patients most likely to progress to a PS/CPAP trial later in the day after sedation has further

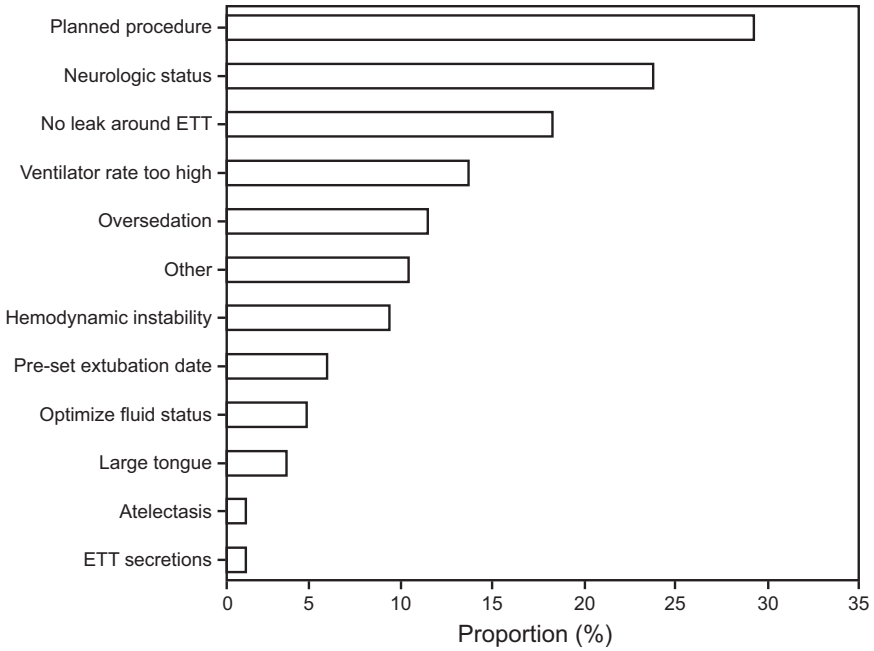

Fig. 3. Reasons to delay extubation despite passing a daily spontaneous breathing trial . ETT = endotracheal tube.

Table 3. Clinical Outcomes by Extubation Readiness Test Method

Variable	All Subjects ($N = 427$)	DSBT ($n = 168$)	PS/CPAP ($n = 128$)	No ERT ($n = 124$)	Unplanned Extubation ($n = 7$)	*P*
Initial respiratory support						<.001
Room air	51 (11.9)	11 (6.6)	10 (7.8)	30 (24.2)	0 (0)	
Nasal cannula	221 (51.8)	79 (47.0)	69 (53.9)	70 (56.5)	3 (42.9)	
HFNC	132 (30.9)	68 (4.5)	43 (33.6)	17 (13.7)	4 (57.1)	
NIV	23 (5.4)	10 (6.0)	6 (4.7)	7 (5.7)	0 (0)	
Extubation failure rate	21 (4.9)	15 (8.9)	4 (3.1)	0 (0)	2 (28.6)	<.001
NIV use in the first 48 h	25 (5.9)	10 (6.0)	7 (5.5)	8 (6.5)	0 (0)	.91

Data are presented as number (%).
DSBT = daily spontaneous breathing trial
PS = pressure support
ERT = extubation readiness test
HFNC = high-flow nasal cannula
NIV = noninvasive ventilation

been optimized. Our DSBT protocol recommends optimizing sedation and re-screening later that the day, but this practice is clinician-dependent and not currently standardized. The Society of Critical Care Medicine's ICU liberation ABCDEF bundle recommends using both spontaneous breathing trials and spontaneous awakening trials to improve patient outcomes[24,25]; however, spontaneous awakening trials are not a common practice in the pediatric population. Another potential solution could be incorporating sedation scoring in ventilator management protocols and ERT, or performing more frequent ERT screening.

The next most common reasons to extubate off our DSBT protocol in which an ERT was performed were breathing frequency and exhaled tidal volume outside target ranges. Bradypnea could be partially related to oversedation, whereas tachypnea and low exhaled tidal volumes could be related to residual respiratory disease, neuromuscular weakness, or undersedation. Because many subjects were extubated despite a breathing frequency above the target or a tidal volume below the target, it may be worth considering adjusting the protocol to tolerate slightly higher breathing frequencies and lower tidal volumes.[5,26] The rapid shallow breathing index combines both breathing frequency and tidal volume (the rapid shallow breathing index equals breathing frequency divided by tidal volume) and has been used to predict extubation success in adults, but

Table 4. Multivariate Analysis of Extubation Failure

Variable	Odds Ratio (95% CI)	*P*
Duration of invasive ventilation	1.000 (0.996–1.005)	.91
Age	0.996 (0.987–1.004)	.31
PRISM III score	1.08 (0.99–1.17)	.069
Postoperative status	1.46 (0.42–5.07)	.55
Primary illness category, respiratory	8.96 (2.49–32.27)	<.001
Method of extubation, DSBT as reference, vs		
PS/CPAP	0.33 (0.10–1.12)	.96
No ERT	N/A	N/A
Unplanned extubation	7.10 (0.76–66.87)	.88
Cerebral palsy	0.98 (0.10–9.97)	.99
Initial respiratory support after extubation, HFNC	1.64 (0.56–4.77)	.37

PRISM = pediatric risk of mortality
DSBT = daily spontaneous breathing trial
PS = pressure support
ERT = extubation readiness test
N/A = not applicable
HFNC = high-flow nasal cannula

only a few pediatric studies.[26-28] There is a lack of strong predictive rapid shallow breathing index values that account for different acceptable breathing frequencies in different age groups in the pediatric population. Prospective randomized controlled trials would be needed to help determine optimal pediatric rapid shallow breathing index values.

The level of PS used in the PS/CPAP group was not standardized and was provider-dependent. This reflects the lack of consensus with regard to the amount of PS required or whether PS is even needed during ERT.[29,30] Although the degree of PS can conceptually affect the tidal volume and breathing frequency, a randomized controlled study is needed to explore the effects of different levels of PS on these physiologic parameters and extubation outcomes.

In the subjects who passed their DSBT but were not extubated until a future calendar day, a planned procedure was the most common documented reason. Flagging patients in the electronic medical records who have passed their DSBT could be one potential way to remind clinicians to extubate the patient after the procedure is completed, providing there are no significant changes in lung compliance, oxygenation, or hemodynamics, and patient sedation-pain status allows. Protocol adjustment to allow for a repeated DSBT following procedures could be added to expedite extubation in these patients.

Neurologic status ranked as the second most common cause of extubation delay. These were subjects who either still required optimization in their sedation-pain status or who were unable to protect their airway for neurologic reasons such as status epilepticus or new neurologic injury. To minimize the proportion of patients who are oversedated, one improvement could be to incorporate sedation assessment tools, for example, the state behavioral score, or other sedation scoring tools into the protocol to assure that the patient is at the appropriate level of sedation.[31,32]

The utility of measuring the leak pressure around the endotracheal tube to predict upper-airway obstruction is controversial in pediatric populations.[22,33] The lack of a leak was the indication for a delay in extubation for 18% of our subjects. This is also a commonly included element in ERT bundles in other studies, and it has been shown to correlate with upper-airway obstruction.[21,34-37] More frequent monitoring of leak pressure, such as measuring it every shift, and the introduction of systemic corticosteroids when leak pressure is above a specific value (20 or 25 cm H_2O) could be incorporated into ventilator management protocols and ERT to minimize these delays.[21,36,38]

Although the median number of DSBTs passed before extubation was 1 regardless of the duration of invasive ventilation, the interquartile ranges demonstrate that subjects intubated for > 24 h passed multiple DSBTs before extubation, which may represent unnecessary delays in extubation (Table 2). Another element of delaying extubation was the time between passing any form of ERT and extubation, with a median time of 7 h, regardless of the duration of invasive ventilation. We believe that this delay could be eliminated by the implementation of respiratory therapist-led extubation rounds as soon as patients pass an ERT, during which the respiratory therapist would extubate the patient to free up clinicians. Studies show that respiratory therapist-driven ERT pathways help improve the timeliness of ERT assessment.[19]

Loberger et al[19] screened pediatric subjects every 3 h to reduce the time between eligibility for ERT and the first ERT attempt. In their study, they were able to decrease that time from 34 to 3 h while simultaneously decreasing the extubation failure rate from 16% to 5%. This differs from the majority of other studies that tended to evaluate subjects every 12 or 24 h.[18,20,26] However, there are many challenges to a more frequent evaluation that are worth mentioning: it increases the work load on bedside respiratory therapists, it does not account for sedation optimization in preparation for extubation or provider preference to perform high-risk extubations during daytime, it will be difficult to assure nil per os status, and it might be challenging to extubate patients after midnight because this could disturb the patient's sleep cycle and reduce family satisfaction.[19,24,39]

Our extubation failure rate was 5% for the total cohort, which is consistent with other studies.[8-10] On univariate analysis, the extubation failure rate was higher in the DSBT group (9%) versus the PS/CPAP group (3%). This is a rather peculiar finding, given that we hypothesized that the PS/CPAP group allowed for more permissive

breathing frequencies and tidal volumes in a provider-dependent manner. Multivariate analysis showed no difference in extubation failure rates between our DSBT and PS/CPAP groups, which suggests that some barriers to extubation, such as targeted breathing frequency and tidal volume, could be relaxed yet still achieve similar extubation success. However, there is some degree of limitation in comparing this because the tidal volume and breathing frequencies were not consistently documented in our electronic medical records for the PS/CPAP group.

Study Limitations and Implications

This study was limited due to its retrospective design. The prevalence of the barriers to extubation reflect our local practices and can only be correlated with our DSBT protocol (which remained unchanged for the duration of the study). The decision to proceed to a PS/CPAP trial and the respiratory modality used after extubation reflect the clinician's preference, which was not standardized or surveyed in this study. Despite these limitations, this study demonstrated common factors that contribute to delays in extubation that providers from other institutions could use when implementing their own protocols.

Conclusions

There are variations of extubation assessment practices at our institution that could lead to delays in liberation from invasive mechanical ventilation. Adjustment to our protocol, such as tolerating higher breathing frequencies and lower tidal volumes, incorporating sedation scoring into the protocol, and implementing respiratory therapists-driven extubation rounds, could potentially be made without significantly affecting extubation failure rates based on our findings. Further quality improvement and prospective studies would be needed to assess for improvement in time to extubation while maintaining comparable extubation failure rates.

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