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ORIGINAL ARTICLE

Neurologic Examination and Extubation Outcome in the Neurocritical Care Unit

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Abstract
Background Extubation failure in the neurocritical care unit (NCCU) is difficult to predict, and is an important source of prolonged intensive care, exposure to morbidity, and increased cost.
Methods In this observational cohort study in the NCCU of a tertiary care hospital, we examined patients undergoing extubation or tracheostomy with >6 h of intubation. Observational data were collected at the time of the decision to extubate or pursue tracheostomy. The primary endpoint was extubation failure within 72 h.
Results A total of 378 tracheostomy versus extubation decisions were made on 339 individuals, resulting in 93 tracheostomies and 285 extubations. The extubation failure rate was 48/285 (16.8%). Individuals who underwent extubation had similar GCS scores [median 10T (IQR 10–11), $P = 0.21$]. Extubation failures had similar rates of pneumonia and fever, chest X-ray (CXR) findings, and admission diagnoses ($P =$ NS). Factors associated with success in univariate analysis included intact gag reflex, normal eye movements, ability to close eyes to command, and ability to cough to command (all $P < 0.05$). In multivariate analysis, the ability to follow four commands (close eyes, show two fingers, wiggle toes, cough to command) was associated with success ($P = 0.01$). ROC analysis identified a significant difference in favor of a multivariate model incorporating four commands over GCS alone ($P = 0.007$).
Conclusion The ability to follow four commands and other examination criteria were strongly associated with extubation success in this observational study. Modeling suggests that specific neurologic examination parameters provide additional predictive information over GCS alone. A prospective, protocol-driven trial is needed to test and expand these findings.

Keywords Neurocritical care · Extubation failure · Mechanical ventilation · Neurology · Neurosurgery · Weaning

Introduction

In the neurocritical care unit (NCCU), a significant percentage of patients require intubation for airway management in the context of their neurologic injury. Prolonged

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intubation in an intensive care unit (ICU) is associated with an increased risk of pneumonia, overall morbidity, mortality, need for tracheostomy, length of stay, and cost [1]. In brain-injured patients, a depressed mental status is associated with longer duration of intubation, even after standard weaning parameters have been met [1]. In addition, extubation failure requiring reintubation has been linked to higher morbidity and mortality [2].

Multiple studies have examined parameters that may predict extubation failure in medical ICU patients [3–7], some of which utilize respiratory maneuvers requiring active patient participation [6, 8]. Applying these data to a neurocritical care population is challenging given the unique deficits that accompany neurologic injury. Studies examining extubation outcomes in patients with neurologic disease have produced conflicting results. For example, one study found that a poor level of consciousness was not independently associated with extubation outcome [1], while a later study found that a low Glasgow Coma Scale (GCS) score was associated with extubation failure [9]. Another study found that the ability to follow four commands was associated with a higher probability of extubation success [8]. More recently, it has been shown that the Four Score does not consistently predict extubation failure [10]. Further research is needed to address these discrepancies and determine the best method to assess extubation readiness in the NCCU.

We hypothesized that extubation readiness in NCCU patients is unique in comparison to medical or surgical ICU patients without brain injury, and is dependent on arousal and corticospinal/bulbar function. Our primary aim was to assess the association of extubation outcome with specific neurologic parameters, ascertained prior to extubation, while controlling for confounding by pulmonary, infectious, and other comorbid conditions. Furthermore, given the conflicting results of prior studies, we sought to compare the utility of GCS versus a focused neurologic examination in the prediction of extubation outcome.

Methods

Study Population

Individuals in this study constituted a prospective cohort of intubated and mechanically ventilated patients in the NCCU at Massachusetts General Hospital (MGH). A total of 339 individuals were enrolled from May 2007 through December 2009, through daily screening, to identify potential study patients. Overall, 378 decision events occurred, resulting in 285 extubations and 93 tracheostomies. Of extubations, 48 (16.8%) required reintubation for extubation failure. The clinical protocol approved by the MGH Institutional Review Board established eligibility for enrollment in this study as (1) patients admitted to the NCCU with the primary diagnosis of central nervous system (CNS) or peripheral nervous system (PNS) disease, including aneurysmal subarachnoid hemorrhage (SAH), stroke, intracerebral hemorrhage (ICH), traumatic brain injury (TBI), subdural hemorrhage (SDH), epidural hemorrhage (EDH), venous sinus thrombosis (VST), CNS infection, spinal cord injury (SCI), brain tumor, neuromuscular disease, seizure, toxidrome, elective neurosurgery, or other CNS/PNS process; (2) patients deemed to be suitable for extubation or tracheostomy by the NCCU attending physician; (3) intubation duration of >6 h. Patients were excluded from the study if they were being extubated in a terminal setting, or if they were admitted to the NCCU without primary CNS or PNS disease. No standardized pulmonary weaning protocol is currently in use in the NCCU at MGH, and so the decision to pursue a spontaneous breathing trial (SBT) and/or extubate was left to the discretion of the attending physician. In many cases, an SBT was not performed because the patient was already on minimal ventilator settings at the time of the decision to extubate, and had no underlying pulmonary disease. Neither universal decision rule regarding level of consciousness nor other metric was used to determine suitability for extubation versus tracheostomy.

Outcomes and Definitions

The primary outcome in this study was extubation failure. Patients were defined as failing extubation if they required reintubation within 72 h of the extubation event. Individuals reintubated for a planned procedure were not counted as failures, nor were individuals reintubated after 72 h. Data on late failures (after 72 h) were recorded, but these individuals were analyzed as successes. Re-analysis after omission of these eight individuals did not alter results significantly. A secondary outcome was the need for tracheostomy. Intubated patients for whom the NCCU attending recommended tracheostomy were enrolled at the time this decision was reached (i.e., not at the time of tracheostomy placement). The same variables were evaluated for this population as the extubation cohort, but these patients were not followed after the decision was made to perform tracheostomy.

Demographic, Infectious, and Pulmonary Data Collection

Baseline study data were collected immediately prior to extubation, or at the time of the decision to pursue tracheostomy. Nursing and/or respiratory therapy staff were questioned regarding the quantity (minimal, moderate, or profuse) and texture (thin, moderate, or thick) of suctioned endotracheal sputum. No attempts were made to quantify sputum texture or quantity, given a lack of standardized methods of evaluating these parameters. Biological and respiratory factors, including heart rate, blood pressure, respiratory rate, oxygen saturation, ventilator settings (mode, pressure support, PEEP, backup rate, FiO_2), tidal volume, recent ABG results, recent chest X-ray (CXR) results, and recent sputum microbiology testing were recorded. The presence of a clinical diagnosis of pneumonia (defined by the primary service based on temperature, WBC count, sputum culture results, and CXR findings), was also recorded.

Other factors which were a priori predicted to be associated with extubation outcome were also obtained [e.g., past history of extubation failure, COPD, congestive heart failure (CHF) with EF $<30\%$, smoking history, asthma and obstructive sleep apnea (OSA)]. Immediately prior to extubation, the presence or absence of an endotracheal cuff leak was ascertained. Cuff leak was assessed qualitatively by deflating the cuff of the endotracheal tube and ascultating the airway for breath sounds, and was determined to be absent if the airway sounds were not audible. Following extubation, the presence of inspiratory stridor was assessed by bedside evaluation. No attempts were made to resolve the diagnoses of stridor or stertor in this study.

Neurologic Examination Data Collection

A focused neurologic examination was performed at the time of enrollment, following the collection of the above data. This examination included GCS scoring (recorded as 3–11T), the ability to follow five verbal commands (“close your eyes,” “stick out your tongue,” “show two fingers,” “cough now,” and “wiggle your toes”), eye movements (recorded as normal or abnormal), cough with suctioning (recorded as present or absent), corneal reflexes (recorded as bilateral, unilateral, or absent) orbicularis strength (recorded as normal, asymmetric, or weak), lower facial strength (recorded as normal, asymmetric, or weak), gag reflex (recorded as present or absent), and gross limb strength (recorded on a scale of 0–5). Because the presence of the endotracheal tube, tape, and oro-lingual edema made it difficult in many cases to ascertain the ability to protrude tongue to command, these data were excluded from the final analysis, leaving results available for the remaining four commands.

Statistical Analysis

Data for this study were analyzed using the STATA v.10 software package for Windows (http://www.stata.com). P-values for all categorical data were computed using Chi-square or Fisher’s exact test. The comparison of continuous variables was performed with Wilcoxon’s non-parametric rank sum test for binary outcomes. The Kruskal–Wallis test was used for categorical outcomes. GCS was analyzed by Wilcoxon rank sum as well as categorically. Analysis of neurologic diagnosis by extubation outcome was performed by Fisher’s exact tests (row-by-column method) to search for statistically significant effects for individual diagnoses on extubation outcome.

For multivariate analyses, logistic regression was used to compare extubation success and failure. This regression analysis was performed with the inclusion of variables achieving $P < 0.1$ in univariate analysis. Two separate multivariate models were employed, one for GCS evaluation, and another for neurologic examination evaluation, due to significant collinearity between these observations [variance inflation factor (VIF) >2]. Variables entered into both models included duration of intubation, past medical history of CHF, COPD, or OSA, and secretion texture. The inclusion of neurologic diagnosis to the multivariate models (as a categorical predictor with mean effect across categories as reference for computation of effect sizes) did not change results (data not shown). Either GCS or a combination of neurologic examination findings were then added to this baseline model. The results of each multivariate regression were compared using a receiver operator characteristic (ROC) analysis by calculating the area under the curve (AUC) when plotting sensitivity by 1-specificity.

Results

Tracheostomy Versus Extubation Comparisons

In this study, 93 tracheostomy decisions were made during enrollment, compared with 285 extubations. Individuals sent for tracheostomy were younger (56.2 years $\pm$ 1.9 vs. 60.6 $\pm$ 1.1, $P < 0.001$), with lower GCS scores [10T (IQR 8–11T) vs. 11T (IQR 10–11T), $P = 0.05$]. The duration of intubation was longer for individuals referred for tracheostomy [5 days (IQR 3–9) vs. 2 days (IQR 1–4), $P < 0.001$], with a greater proportion qualifying for a clinical diagnosis of pneumonia (51 vs. 26%, $P < 0.001$). 24/93 (26%) tracheostomies were performed on individuals who had a previous record of failed extubation attempt. No individual with a GCS $<$7T was allowed a trial of extubation. Because the goal of this study was to identify predictors of extubation failure, individuals receiving tracheostomies were excluded from the remainder of analyses.

Demographic, Pulmonary, and Infectious Comparisons

The demographics, medical history, and primary diagnoses of extubated individuals are shown in Table 1. Patients with pulmonary comorbidities such as COPD or OSA were more likely to fail extubation ($P = 0.02$ and $P = 0.05$, respectively). There was no difference in extubation outcome by primary neurologic diagnosis ($P = 0.12$) (Table 1). Medications did not have a significant impact on extubation failure, with no significant difference seen in the use of benzodiazepines, antipsychotics, opioids, or antiepileptic medications between successes and failures (data not shown, all $P =$ NS).

There was no significant difference in extubation outcome when comparing fever, clinical pneumonia, or CXR findings (Table 2). Individuals with thick secretions were more likely to fail extubation (32 vs. 17%, $P = 0.02$), but there was no difference between groups for secretion volume ($P = 0.12$). Pulmonary mechanical variables and ABG results on the day of extubation were also not associated with extubation outcome (Table 2). Rapid shallow breathing index (RSBI) values were all <105 in individuals allowed a trial of extubation, with no significant difference in RSBI between successes and failures ($P = 0.48$). There was likewise no difference between outcomes for individuals with PaO_2/FiO_2 ratio >300 ($P = 0.33$).

Neurologic Examination Comparisons

Individuals who failed extubation had no significant difference in GCS scores compared with those who were successful ($P = 0.21$), but in categorical analysis, there was a trend for individuals with GCS 7–9T to be more likely to fail extubation than those with GCS 10T or 11T ($P = 0.07$) (Table 3). Individuals who failed extubation were significantly less likely to close their eyes or cough on command ($P = 0.04$ and $P = 0.01$), and were less likely to have a normal gag reflex ($P = 0.02$) or normal eye movements ($P = 0.02$). Conversely, the ability to follow each of four commands (close eyes, show two fingers, wiggle toes, and cough) was associated with extubation success ($P = 0.01$).

Multivariate Analyses

All the variables found to be associated with extubation failure with $P < 0.1$ in univariate analysis were included in two multivariate models comparing extubation outcomes (Table 4). Thick secretion texture and a diagnosis of COPD

Table 1 Clinical characteristics, past medical history, and neurologic diagnoses

	Extubation failure	Extubation success	*P*-value
Age	60.2 (18.0)	62.4 (15.0)	0.41
Gender (% female)	43.8	37.5	0.42
Race (% caucasian)	87.5	82.3	0.38
Duration of intubation (days)	3 (2–5)	2 (1–4)	0.05
H/O smoking (%)	39.6	34.6	0.51
COPD (%)	25.0	13.4	0.02
CHF (%)	14.6	5.9	0.06
OSA (%)	12.5	4.6	0.05
Neurologic diagnosis, *n* (%)			0.12
Stroke	12 (25.0)	51 (21.5)	
ICH	7 (14.6)	38 (16.0)	
SAH	8 (16.7)	28 (11.8)	
SDH	6 (12.5)	17 (7.2)	
EDH	0 (0.0)	2 (0.8)	
TBI	4 (8.3)	26 (11.0)	
VST	1 (2.1)	0 (0.0)	
Tumor	4 (8.3)	18 (7.6)	
Neuromuscular disease	1 (2.1)	3 (1.3)	
SCI	1 (2.1)	9 (3.8)	
Toxidrome	2 (4.2)	1 (0.4)	
Seizure	0 (0.0)	24 (10.1)	
Infection	1 (2.1)	5 (2.1)	
Elective surgery	1 (2.1)	9 (3.8)	
Other	0 (0.0)	6 (2.5)	

For age, mean and standard deviation are listed. For duration of intubation, median and interquartile ranges are shown. For all other variables, percentages of patients for are shown in parentheses, categorized by outcome

CHF congestive heart failure, *COPD* chronic obstructive pulmonary disease, *EDH* epidural hemorrhage, *OSA* obstructive sleep apnea, *SCI* spinal cord injury, *VST* venous sinus thrombosis

Table 2 Infectious signs, secretions, pulmonary, and ventilatory characteristics

	Extubation failure	Extubation success	*P*-value
Fever in prior 24 h, *n* (%)	8 (16.7)	38 (16.0)	0.99
Clinical pneumonia, *n* (%)	14 (29.2)	60 (25.3)	0.58
Antibiotics for pneumonia, *n* (%)	14 (29.2)	57 (24.3)	0.72
CXR not clear, *n* (%)	14 (29.2)	87 (36.7)	0.41
Focal airspace disease, *n* (%)	14 (41.2)	51 (34.2)	0.55
Secretion texture			0.024
Thin, *n* (%)	20 (42.5)	148 (62.7)	
Moderate, *n* (%)	12 (25.5)	47 (19.9)	
Thick, *n* (%)	15 (31.9)	41 (17.4)	
Secretion volume			0.12
Minimal, *n* (%)	24 (51.0)	152 (64.4)	
Moderate, *n* (%)	22 (46.8)	74 (31.4)	
Profuse, *n* (%)	1 (2.1)	10 (4.4)	
pH	7.44 (7.41–7.46)	7.42 (7.39–7.45)	0.11
PaO_2 (torr)	127 (93–149)	127 (104–156)	0.30
$PaCO_2$ (torr)	42 (36–44)	40 (36–44)	0.85
Serum HCO_3 (mEq/l)	26.8 (23.6–28.6)	25.0 (23.0–27.6)	0.34
Tidal volume (cc)	500 (450–600)	500 (400–600)	0.78
RR (breath/min)	16 (14–19)	16 (13–19)	0.48
RSBI	33 (27–42)	32 (24–40)	0.48
PaO_2/FiO_2 >300, *n* (%)	26 (54.2)	141 (62.7)	0.33

Values shown are medians and interquartile ranges unless otherwise specified as *n* (%)

CXR chest X-ray, *RR* respiratory rate, *RSBI* rapid shallow breathing index

Table 3 Neurologic evaluation data

	Extubation failure	Extubation success	*P*-value
GCS[a]	10T (10–11)	10T (10–11)	0.21
GCS, *n* (%)[b]			0.074
11T	24 (50.0)	141 (59.8)	
10T	14 (29.2)	68 (28.8)	
7T–9T	10 (20.8)	27 (8.0)	
Close eyes, *n* (%)	28 (58.3)	176 (74.2)	0.035
Show two fingers, *n* (%)	28 (58.3)	163 (68.8)	0.18
Wiggle toes, *n* (%)	32 (66.7)	175 (73.8)	0.37
Cough to command, *n* (%)	19 (39.6)	143 (60.3)	0.01
All four commands, *n* (%)	16 (33.3)	128 (54.0)	0.01
Intact gag reflex, *n* (%)	31 (64.6)	191 (81.3)	0.019
Cough to suctioning, *n* (%)	46 (95.8)	228 (96.2)	0.99
Normal eye movements, *n* (%)	26 (54.2)	171 (72.2)	0.017
Normal upper face, *n* (%)	36 (75.0)	182 (77.4)	0.89
Normal lower face, *n* (%)	27 (56.3)	166 (70.3)	0.14

Percentages of patients for each variable are shown in parentheses, categorized by outcome. For GCS scoring, the maximum possible score for this study was 11T, given the inability to assess verbal output in an intubated patient. Close eyes, cough to command, show two fingers, and wiggle toes are included in the ability to follow four commands

GCS Glasgow Coma Scale score

[a] By Wilcoxon non-parametric rank sum

[b] Fisher's exact test (3 × 2 row/column method)

retained significance in both multivariate analyses ($P < 0.05$). In categorical multivariate analysis of GCS in our cohort, a GCS of 7–9T was associated with extubation failure (OR failure 2.91, 95% confidence interval (95% CI) 1.2–7.1, $P = 0.02$). The ability to follow all four selected commands (close eyes, cough to command, show two fingers, and wiggle toes) was associated with extubation success (OR failure 0.43, 95% CI 0.22–0.86, $P = 0.02$), while gag reflex and normal eye movements did not retain significance.

The two multivariate models were compared in receiver–operator characteristic (ROC) analysis (Table 4). The model containing the elemental neurologic examination was found to be more predictive of extubation outcome than the model containing the GCS alone (AUC 0.75 vs. 0.71, $P = 0.007$).

Post-Extubation Comparisons

Data on pre-extubation endotracheal cuff leak and post-extubation stridor was available for 203/285 extubations. Of these, 25 (12%) had an absent cuff-leak, and 19 (9%) had post-extubation stridor. In univariate analysis, the presence of stridor was significantly associated with extubation failure ($P = 0.01$), while absence of cuff leak was not ($P = 0.24$). In a four-way multivariate analysis of cuff-leak and stridor, the absence of cuff-leak combined with presence of stridor

Table 4 Multivariate models for GCS score and neurologic examination parameters

Predictor	OR	95% CI	*P*-value
Multivariate model with GCS score			
COPD	2.65	1.12–6.27	0.026
CHF	2.32	0.79–6.80	0.12
OSA	2.10	0.64–6.90	0.22
Duration intubation	1.07	0.95–1.20	0.25
Secretion texture (thick)	2.70	1.28–5.69	0.011
GCS = 11T	Ref.	Ref.	Ref.
GCS = 10T	1.23	0.56–2.69	0.60
GCS = 7T–9T	2.91	1.19–7.12	0.019
LR $\chi^2 = 19.45$, AUC = 0.71			
Multivariate model with detailed neurologic examination			
COPD	2.40	1.01–5.72	0.045
CHF	2.14	0.73–6.23	0.16
OSA	2.11	0.64–7.02	0.22
Duration intubation	1.01	0.90–1.14	0.86
Secretion texture (thick)	2.34	1.09–4.99	0.028
Four command	0.43	0.22–0.86	0.018
Gag reflex	0.55	0.26–1.16	0.12
Normal eye movements	0.57	0.28–1.18	0.13
LR $\chi^2 = 29.45$, AUC = 0.75			

Odds ratios (ORs) reflect odds of extubation failure. Close eyes, cough to command, show two fingers, and wiggle toes are included in the ability to follow four commands. AUC represents the area under the curve specified by the model, plotting sensitivity versus 1-specificity

AUC area under curve, *CHF* congestive heart failure, *COPD* chronic obstructive pulmonary disease, *GCS* Glasgow Coma Scale score, *LR* likelihood ratio, *OSA* obstructive sleep apnea

Table 5 Multivariate analysis of pre-extubation cuff leak and post-extubation stridor

	n	OR	95% CI	*P*-value
Cuff leak yes, stridor no	168	1.00 (Ref.)	Ref.	Ref.
Cuff leak no, stridor no	15	0.79	0.17–3.69	0.76
Cuff leak yes, stridor yes	14	2.27	0.65–7.91	0.20
Cuff leak no, stridor yes	6	10.2	1.78–58.6	0.009

Odds ratios (ORs) reflect odds of extubation failure. Analysis represents a four-tiered multivariate analysis using present pre-extubation cuff leak and absent post-extubation stridor as the reference state

Ref. reference

was significantly associated with extubation failure (OR 10.2, 95% CI 1.8–58.6), $P = 0.009$) (Table 5).

Discussion

In this prospective observational cohort of 285 extubations in the NCCU, a multivariate model incorporating specific aspects of the neurologic examination was more predictive of extubation outcome than a model utilizing GCS alone. The ability to follow all four commands (close eyes, cough to command, show two fingers, and wiggle toes) was associated with extubation success both in univariate and multivariate analysis. GCS was not associated with outcome when using a rank-sum based analysis, but in a categorical analysis, a GCS of 7–9T was associated with an increased risk of extubation failure.

The analysis of GCS was complicated in our study by the fact that no patient with a GCS score $<$7T was allowed a trial of extubation. Although no protocol was in place in our NCCU at the time of this study, this observation suggests that the treatment teams did not feel that individuals with GCS $<$7T would be likely to tolerate extubation. We are, therefore, unable to extend our findings of association between low GCS (7–9T) and extubation failure to even lower GCS scores. Our categorical analysis of GCS does support the concept that low GCS scores provide some predictive information for extubation outcome, but without inclusion of additional individuals with low GCS scores, a more definitive result cannot be ascertained.

The reintubation rate in our study (16.8%) was similar to the reintubation rates quoted by Coplin et al. [1] (17.2%) and Salam et al. [8] (15.9%). In the study by Namen et al. [9], the extubation failure rate was significantly higher, at 38%. A more recent study performed on in brain- and spine-injured patients in a neurocritical care wing of an emergency room showed a 12.5% reintubation rate in the control group, which dropped to 5% with institution of a weaning protocol, which primarily included RSBI and arterial blood gas results [11]. The protocol used in their analysis required a GCS score $\geq$8 for consideration of extubation, which may have excluded patients for whom the neurologic status was the primary limitation to extubation success. Namen et al. found an excess of extubation failures in patients with GCS scores $<$8, while Coplin et al. demonstrated an 80% extubation success rate in patients with GCS $<$8. This lack of consensus illustrates the need for further investigation of extubation rules for individuals with low GCS scores.

Salam et al. [5] assessed mental status by the ability to follow four commands: open eyes, track examiner, grasp hand, and protrude tongue. In our study, we prompted patients with five commands, four of which were different from those used by Salam et al. The specific commands used in the evaluation are likely important. For instance, opening eyes to command could reflect an arousal event to a novel stimulus or a startle reaction, rather than a volitional event. Regarding and following a face can occur without volition, as the human face is a strong stimulus for fixation. Grasping of a hand can be primitive reflex, not necessarily indicative of a patient following the command.

In contrast, closing eyes to command, showing two fingers, wiggling toes, and coughing to command require relatively preserved consciousness, attention, intact long-tract motor pathways, and muscle coordination. Tongue protrusion was included in both our study and the study by Salam et al., but we feel that this command may be of limited utility because of practical ascertainment concerns due to the presence of the endotracheal tube and frequent oro-lingual edema.

A recent study followed respiratory rate, minute ventilation, tidal volume, RSBI, negative inspiratory force (NIF), and PaO_2/FiO_2 ratio, and found no correlation between any of these variables and extubation failure in a neurocritical care population [10]. Another study found that weaning parameters were more difficult to apply to patients intubated for neurologic reasons in comparison with patients intubated for primary pulmonary reasons [7]. Both studies correlate well with the lack of association between measured pulmonary variables and the outcome of extubation in our cohort. These results point toward a common issue of airway management rather than pulmonary mechanics as the primary cause of extubation failure in the NCCU. The results of the current study contribute to growing evidence supporting the utility of using basic, testable neurologic abilities to predict post-extubation airway maintenance.

The absence of sufficient endotracheal cuff leak has been associated with post-extubation stridor [12, 13]. The frequency of absent cuff leak (12%) and post-extubation stridor (9%) in our cohort compare favorably with previously quoted rates [13, 14]. While in prior studies stridor rarely led to reintubation [14, 15], we observed a strong association between stridor and extubation failure. While our results are not conclusive, they demonstrate the need for additional investigation into the causes and treatments of post-extubation inspiratory stridor and stertor in the NCCU.

There are several limitations to our study. As with any observational cohort study, unmeasured variables may have played a role in outcome. The study was unblinded, and reporting and observation biases could have impacted the results. There are also clinical data points which were not collected prospectively that could have increased the risk of extubation failure. For instance, a positive fluid balance in the 24 h before extubation has been shown to predict extubation failure [16]. This is possibly relevant to our population, as NCCU patients often receive aggressive hydration to maintain adequate cerebral perfusion. There may have been underreporting of potentially confounding prior medical conditions, such as COPD, smoking, or OSA, since many of the patients included in this study were not able to report their own medical history due to their neurological illness. We obtained this history from family members or the medical record when available, but this was not always possible. Quantitative measures were not used to estimate sputum thickness or volume, primarily because a standardized method for these measurements is not in clinical use. The qualitative estimates of these variables used in our study are commonplace, but their interpretation and generalizability are limited by the lack of a quantitative standard.

Our results suggest that a focused neurologic examination may be of higher utility than the GCS alone to predict extubation outcome. A prospective, protocol-driven study of extubation in the NCCU that takes into account elements of the neurologic examination in addition to commonly accepted pulmonary criteria is needed, both to validate the results of our observational study, and to build toward a prediction rule that improves extubation outcomes in our patient population.

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