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Subjective Assessment of Motor Function by the Bedside Nurses in Mechanically Ventilated Surgical Intensive Care Unit Patients Predicts Tracheostomy

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Abstract

Objective: In many institutions, intensive care unit (ICU) nurses assess their patients' muscle function as part of their routine bedside examination. We tested the research hypothesis that this subjective examination of muscle function prior to extubation predicts tracheostomy requirement.

Methods: Adult, mechanically ventilated patients admitted to 7 ICUs at Beth Israel Deaconess Medical Center (BIDMC) between 2008 and 2019 were included in this observational study. Assessment of motor function was performed every four hours by ICU nurses. Multivariable logistic regression analysis controlled for acute disease severity, delirium risk assessment through the confusion assessment method for the ICU (CAM-ICU), and pre-defined predictors of extubation failure was applied to examine the association of motor function and tracheostomy within 30 days after extubation.

Results: Within 30 days after extubation, 891 of 9609 (9.3%) included patients required a tracheostomy. The inability to spontaneously move and hold extremities against gravity within 24 h prior to extubation was associated with significantly higher odds of 30-day tracheostomy (adjusted OR 1.56, 95% CI 1.27–1.91, $p < 0.001$, adjusted absolute risk difference (aARD) 2.8% ($p < 0.001$)). The effect was magnified among patients who were mechanically ventilated for >7 days (aARD 21.8%, 95% CI 12.4 −31.2%, p-for-interaction = 0.015).

Conclusions: ICU nurses' subjective assessment of motor function is associated with 30-day tracheostomy risk, independent of known risk factors. Muscle function measurements by nursing staff in the ICU should be discussed during interprofessional rounds.

Keywords

mechanical ventilation, nursing assessment, muscle strength, tracheostomy, ventilator weaning, critical care nursing

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Introduction

In critically ill patients, muscle weakness is associated with prolonged need for mechanical ventilation, increased risk of extubation failure and longer intensive care unit (ICU) and hospital length of stay.[1–6] Voluntary contraction force can be assessed at the bedside through manual muscle testing using the Medical Research Council (MRC) scale. The MRC scale sum score is a valid and reliable method for manual muscle testing across a wide range of muscles and predicts outcomes of patients who are critically ill.[1] The Subjective Motor Assessment RouTine (SMART) rating, which is a simplified version of the MRC scale, became a routine clinical assessment of motor function by ICU nurses.[7,8] In contrast to the MRC scale, the SMART rating is an observational assessment that can be performed even when the patient is uncooperative, intubated and/or sedated.

In this observational multicenter study, we hypothesized that the ICU nurses' SMART rating prior to extubation, as an integral part of the nursing assessment in the ICU, would predict tracheostomy requirement within 30 days after extubation.

Methods

Study Design

A pilot study was conducted as detailed in section I of supplemental material 1. To ensure rigorous confounder control, the primary analysis was performed in a large ICU registry including patients who underwent surgery between February 2008 and January 2019 at Beth Israel Deaconess Medical Center (BIDMC). The study was approved by the Partners Healthcare Institutional Review Board (protocol 2015P002568) and the Committee on Clinical Investigations at BIDMC (protocol 2019P000517) with a waiver of written informed consent.

Study Cohort

Adult patients (18 years old) who had surgery during their hospital stay, required invasive mechanical ventilation through an endotracheal tube in the ICU, and were subsequently extubated were eligible for this study. Patients were included regardless of requiring reintubation. Patients were considered ineligible if they had a pre-existing tracheostoma. Patients were excluded if a tracheostomy was placed without an extubation attempt or if they underwent terminal extubation (including comfort measure orders). The first invasive mechanical ventilation period and corresponding initial extubation during the same hospital stay were considered as the index ventilation period.

Decisions regarding patients' critical care plans, including readiness for extubation, were made by the interdisciplinary ICU team consisting of surgical and medical intensivists, respiratory therapists, physical therapists, and ICU nurses. Per standardized protocol, spontaneous awakening and breathing trials (SBT) were performed prior to extubation (supplemental material 2).[9] Patients were placed on the spontaneous ventilation mode with a PEEP of 0 cmH_2O, a pressure support of 5cmH_2O and a F_IO_2 $\leq$50% for 30 min. Criteria to terminate an SBT included oxygen desaturation, tachypnea, arrhythmias (tachy- or bradycardia), hyper- or hypotension, paradoxical breathing or signs and symptoms of severe anxiety. Failure of extubation was determined based on the following parameters: decreasing PaO_2/F_IO_2-ratio, inability to cough and clear secretions, increasing rapid shallow breathing index, visible signs and symptoms of increased work of breathing.

Patients were followed for up to 30 days or until hospital discharge. Data collection methods at both institutions are described in detail in supplemental material 1, section IIa.

Subjective Motor Assessment RouTine (SMART)

The bedside nurses in the ICU routinely assess patients' motor function and document the subjective rating for each extremity on a five-point numeric rating scale as follows (supplemental figure 1): no movement at all (0), visible movement in bed without lifting extremity (1), ability to lift extremities briefly but not hold against gravity (2), ability to lift and hold extremities against gravity (3), and normal motor activity (4).

We calculated the mean across all four extremities and examined the highest SMART rating within 24 h prior to initial extubation. Due to an imbalanced distribution, we summarized the numerical variable in three groups: not able to hold against gravity (low SMART rating of 0-2), ability to move and hold against gravity (intermediate SMART rating of 3) and normal motor activity (high SMART rating of 4).

Primary Analysis

Spontaneous motor activity prior to extubation was previously identified as a predictor of reintubation.[8] Logistic regression analysis with a significance level of 0.05 was performed to examine the association of SMART rating within 24 h prior to extubation and the primary outcome, 30-day tracheostomy requirement, defined as tracheostomy or death within 30 days of initial extubation (supplemental material 1, section IIb).

A priori defined confounding variables were chosen based on available literature and clinical plausibility[8,10–15]: age, history of home oxygen dependency, history of congestive heart failure, fluid balance within 24 h prior to extubation, highest blood urea nitrogen and lowest hemoglobin within 24 h prior to extubation, number of spontaneous breathing trials performed prior to extubation, duration of invasive mechanical ventilation and mean minute ventilation. To examine potential added value of this subjective nursing assessment to other routine critical care risk assessments, Acute Physiology and Chronic Health Evaluation II (APACHE II), delirium risk (confusion assessment method for the intensive care unit (CAM-ICU)) and sedation/agitation level assessment (based on Richmond Agitation-Sedation Scale (RASS)) within 24 h prior to extubation were included in the primary multivariable regression model (supplemental material 1, section IIc).[16,17]

Sensitivity Analyses

The robustness of our findings was tested in several sensitivity analyses, including additional confounder adjustments, subgroup analyses and multiple imputation by chained equation as an alternative method to address missing information. To adjust for changes in the population at risk across the 30-day follow-up period, a time-to-event analysis using a multivariable Cox regression model was performed. Details are described in supplemental material 1, section III.

Exploratory Analyses

With an exploratory intent, we examined potential predictors of a low SMART rating (inability to hold against gravity) using univariate logistic regression analysis (supplemental material 1, section IVa). Contingent on a significant association between a candidate predictor and a low SMART rating, these candidate predictors were included as additional confounders in the primary model in a post-hoc sensitivity analysis to determine whether SMART would remain independently associated with 30-day tracheostomy requirement.

To identify patient populations in whom the difference in tracheostomy risk may be more pronounced, we performed interaction term analyses to examine the following potential effect modifiers: age, ethnicity, duration of invasive mechanical ventilation, history of congestive heart failure, home oxygen dependency, proportion of deep sedation days during the entire mechanical ventilation period,[18] neurology or neurosurgery as the primary service and cardiac surgery as the primary service (supplemental material 1, section IVb).

Statistical Analysis

Variables are summarized using mean (standard deviation, SD) or median and interquartile range (IQR), as appropriate; categorical variables are reported as absolute frequencies and percentages. To assess the association between SMART rating within 24 h prior to extubation and 30-day tracheostomy requirement, logistic regression analysis was performed comparing patients who were not able and patients who were able to hold against gravity to patients with normal activity within 24 h prior to extubation as assessed by the bedside nurse. The primary regression model was conducted using forced variable entry and evaluated to ensure that the estimations could be interpreted conventionally. The linearity assumption was tested for all continuous variables in the primary regression model. In case of non-linearity, variables were divided into equally sized tertiles or clinically relevant categories. Concordance c-statistic, equivalent to a receiver-operating characteristics (ROC) curve analysis, was performed to determine model discrimination. Model calibration of the primary analysis was evaluated by the Hosmer-Lemeshow test and a reliability plot, which analyzed the agreement between the observed and estimated outcomes (supplemental material 1, section IId).

We considered a two-tailed p-value below 0.05 as statistically significant. Results are reported as odds ratios (OR) with 95% confidence intervals (95% CI). All described analyses were performed with STATA (Version 13, StataCorp LP, College Station, TX).

Power analysis. In our primary cohort, the bedside nurse observed an inability to hold against gravity in 2348 patients and normal activity in 3028. Based on the pilot study,[8] tracheostomy rates were 6.9% in patients who had normal activity and 15.7% in patients unable to hold against gravity. We will have >99% power to detect an expected difference of 9% at 0.05 type I error rate using a two-sided Z-test with unpooled variance. In addition, assuming incidence of 6.9% for tracheostomy under the null hypothesis, the current sample size achieves 90% power to detect a minimum difference in rates of 2.3%, at 0.05 type I error rate using a two-sided Z-test with unpooled variance.

Results

Primary Analysis

At BIDMC, 11,400 adult patients were eligible for inclusion in this study. A total of 864 (7.6%) were excluded, 361 due to terminal extubation and 503 due to tracheostomy placement without an extubation attempt. 925 (8.8%) of the remaining 10,534 patients were not considered for analysis in the complete case cohort, which comprised 9609 patients, due to missing information for confounding variables (Figure 1).

SMART rating was performed and documented by the ICU nurse at a median of 6 times per day (IQR: 4−10). Within 24 h prior to extubation, the bedside nurse observed an inability to hold against gravity in 2348 (24.4%) patients, ability to hold against gravity in 4233 (44.1%) patients and normal activity in 3028 (31.5%) patients. Patients included in the main study cohort had a mean age of 61.4 years (SD: 15.1), with a median APACHE II score of 20 (IQR: 16-25) and a median duration of mechanical ventilation of 19.3 h (IQR: 9.9 −48.3.); 5911 (61.5%) were male. Baseline characteristics by SMART group are displayed in Table 1.

Within 30 days after initial extubation, 891 (9.3%) patients were tracheotomized or had died. Median time to tracheostomy requirement was 9 days (IQR: 4-16, supplemental Figure 2). Tracheostomy requirement was significantly higher in patients not able to hold against gravity as observed by the bedside nurse within 24 h prior to extubation (277/2348, 11.8%) compared to patients with normal activity (207/3028, 6.8%; adjusted OR 1.56, 95% CI 1.27−1.91, $p < 0.001$), while there was no significant difference between patients who were able to hold against gravity (407/4233, 9.6%) and patients with normal activity prior to extubation after applying the full confounder model (adjusted OR 1.16, 95% CI 0.97−1.40, $p = 0.11$) (Figure 2, supplemental table 1). Including adjustment for CAM-ICU and sedation level assessment within 24 h prior to extubation, the 30-day tracheostomy risk among patients unable to hold

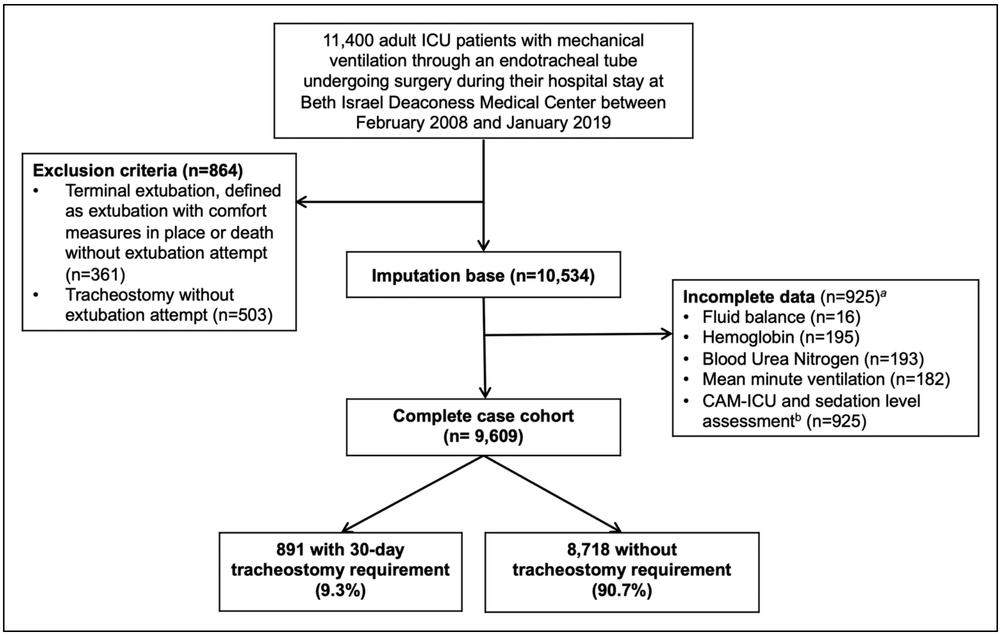

Figure 1. Study flow.[a] Multiple exclusion criteria may apply; missing information of listed variables within 24 h prior to extubation. [b] Sedation level assessment was RASS (Richmond Agitation Sedation Scale) or SAS (Riker Sedation- Agitation Scale), see supplemental section IIc. Abbreviations: ICU = Intensive care unit, CAM-ICU = Confusion Assessment Method for the Intensive Care Unit.

extremities against gravity prior to extubation was higher by an adjusted absolute difference of 2.8% compared to normal activity (95% CI 1.5−4.1%, p < 0.001) (Figure 3).

Sensitivity Analyses

The results remained robust across several sensitivity analyses including addition of individual confounders to the primary model (primary service, frequency of suctioning and highest Glasgow Coma Scale [GCS] within 24 h prior to initial extubation) as well as in a cohort following multiple imputation by chained equations. Accounting for at-risk variations across the 30-day period after extubation in Cox regression analysis including the full primary confounder model confirmed our main findings (supplemental material 1, supplemental table 1 and section III).

Exploratory Analyses

Patients characterized by the following factors were significantly more likely to reach a lower SMART rating within 24 h prior to extubation: deeper level of sedation within 24 h prior to extubation, neurological impairment identified by a primary neurological problem and a lower GCS within 24 h prior to extubation, a higher level of morbidity burden characterized by older age, longer ICU and hospital length of stay prior to extubation as well as higher disease severity (higher APACHE II score, longer duration of mechanical ventilation) and any hyperkalemia within 24 h prior to extubation (Table 2; supplemental material 1, section IVa).

The area under the ROC curve of a multivariable model including all described factors to predict the inability to hold against gravity within 24 h prior to extubation was 0.70 (95% CI: 0.68−0.71). Even after adding all significant predictors of a low SMART rating to our primary confounder model, the inability to hold extremities against gravity within 24 hours prior to extubation remained a significant independent predictor of higher 30-day tracheostomy requirement (adjusted OR 1.48, 95% CI 1.19−1.83, p < 0.001).

Interaction analysis revealed that the adjusted absolute risk difference (aARD) for tracheostomy between patients unable to hold against gravity and those moving normally prior to extubation as observed by the bedside nurse was magnified in patients who were mechanically ventilated for >7 days (aARD 21.8%, 95% CI 12.4−31.2%), patients < 70 years of age (aARD 4.1%, 95% CI 2.6−5.7%) as well as patients without a history of congestive heart failure (aARD 3.2%, 95% CI 1.8−4.6%) (Figure 3; supplemental material 1, supplemental table 2).

Discussion

Subjective assessment of muscle function by ICU nurses predicts tracheostomy within 30 days after extubation in critically ill surgical patients. This nursing assessment of motor function explains variance that cannot be explained by known risk factors of tracheostomy and revealed that some patients present with very severe muscle weakness prior to an extubation attempt, even after a relatively short duration of mechanical ventilation, which was associated with magnified tracheostomy risk.

Table 1. Patient Characteristics by Spontaneous Motor Activity at Beth Israel Deaconess Medical Center.

Patient characteristics	Unable to hold against gravity (n = 2348)	Ability to hold against gravity (n = 4233)	Normal activity (n = 3028)
30-day tracheostomy requirement	277 (11.8%)	407 (9.6%)	207 (6.8%)
Patient characteristics			
Age, mean ± SD	65.59 ± 14.45	65.07 ± 14.69	61.51 ± 15.75
Gender, male	1455 (62.0%)	2497 (59.0%)	1959 (64.7%)
BMI, mean ± SD	29.02 ± 7.51	29.10 ± 7.53	28.87 ± 7.14
APACHE II, median (IQR)	21 (17, 26)	21 (17, 25)	19 (15, 23)
Congestive heart failure, n (%)	528 (22.5%)	955 (22.6%)	538 (17.8%)
Home oxygen dependency, n (%)	89 (3.8%)	224 (5.3%)	169 (5.6%)
CCI, median (IQR)	1 (0, 4)	1 (0, 4)	1 (0, 3)
Characteristics of ICU admission			
Sedation level within 24 h prior to extubation			
Deep sedation (RASS > 1)	455 (19.4%)	393 (9.3%)	207 (6.8%)
Moderate sedation (RASS 0-1)	831 (35.4%)	1733 (40.9%)	727 (24.0%)
Adequate sedation (RASS -1 and -2)	888 (37.8%)	1618 (38.2%)	1485 (49.0%)
Agitated (RASS ≤ -3)	174 (7.4%)	489 (11.6%)	609 (20.1%)
CAM-ICU positive within 24 h prior to extubation	308 (13.1%)	955 (22.6%)	591 (19.5%)
Number of spontaneous breathing trials, median (IQR)	1 (1, 1)	1 (1, 2)	1 (1, 1)
Fluid balance within 24h prior to extubation (L), median (IQR)	2.28 (-0.03, 4.53)	2.11 (-0.02, 4.25)	1.76 (0.09, 3.82)
Highest blood urea nitrogen within 24h prior to extubation, median (IQR)	6.43 (4.64, 10.00)	6.43 (4.64, 10.00)	6.07 (4.29, 9.29)
Lowest hemoglobin within 24h prior to extubation, mean ± SD	9.45 ± 1.69	9.30 ± 1.75	9.54 ± 1.86
Mean minute ventilation in the 24h prior to extubation (L/min), mean ± SD	8.60 ± 1.89	8.33 ± 1.87	8.37 ± 1.70
Duration of invasive mechanical ventilation (h), median (IQR)	20.26 (9.47, 65.57)	20.17 (9.94, 53.99)	18.02 (10.09, 36.65)
ICU admission category			
Elective	1497 (64.1%)	2713 (64.4%)	1907 (63.2%)
Emergent	758 (32.4%)	1341 (31.8%)	992 (32.9%)
Trauma	82 (3.5%)	161 (3.8%)	118 (3.9%)
Primary service of hospitalization			
Cardiology	68 (2.9%)	154 (3.6%)	137 (4.5%)
Cardiac surgery	1166 (49.7%)	1746 (41.2%)	1151 (38.0%)
General surgery	322 (13.7%)	741 (17.5%)	441 (14.6%)
Urology	7 (0.3%)	20 (0.5%)	23 (0.8%)
Gynecology	6 (0.3%)	17 (0.4%)	28 (0.9%)
Medicine	188 (8.0%)	385 (9.1%)	436 (14.4%)
Neurology	91 (3.9%)	115 (2.7%)	37 (1.2%)
Neurosurgery	165 (7.0%)	328 (7.7%)	236 (7.8%)
Obstetrics	4 (0.2%)	11 (0.3%)	27 (0.9%)
Oncology	23 (1.0%)	53 (1.3%)	58 (1.9%)
Orthopedics	84 (3.6%)	152 (3.6%)	67 (2.2%)
ENT	4 (0.2%)	5 (0.1%)	24 (0.8%)
Plastic surgery	11 (0.5%)	18 (0.4%)	16 (0.5%)
Thoracic surgery	39 (1.7%)	148 (3.5%)	113 (3.7%)
Trauma surgery	68 (2.9%)	179 (4.2%)	115 (3.8%)
Vascular surgery	102 (4.3%)	161 (3.8%)	119 (3.9%)

APACHE II = Acute Physiology and Chronic Health Evaluation; BMI = Body mass index; CAM-ICU = Confusion Assessment Method for Intensive Care Unit; CCI = Charlson Comorbidity Index; ENT = Ear, Nose and Throat; ICU = Intensive Care Unit; IQR = interquartile range; RASS = Richmond Agitation-Sedation Scale; SD = standard deviation.

Our study supports the view that ICU acquired muscle weakness is associated with weaning failure such as delayed extubation and prolonged ventilation.[1–3,5,19,20] Up to 80% of individuals who show signs of limb muscle weakness also develop diaphragmatic weakness[21,22] which may result in neuromuscular respiratory failure leading to unplanned ICU readmission and unexpected death.[23] Our findings confirm the important interplay between muscle weakness and adverse respiratory outcome in critically ill patients by identification of muscle weakness as an independent risk factor for tracheostomy within 30 days after extubation in the ICU.

In our study, we controlled for known predictors of tracheostomy such as age, APACHE II score, comorbidities, metabolic disturbances, and neurological dysfunction (level of sedation and delirium risk).[8,10–12] This suggests that muscle weakness is not only an indicator of the severity of disease but also an independent predictor of the inability to protect the airway and of diaphragmatic dysfunction for an extended period of time.

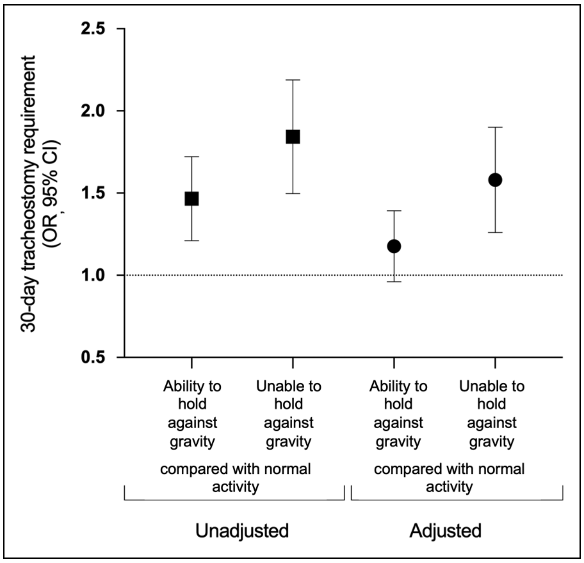

Figure 2. SMART and 30-day tracheostomy requirement. Abbreviations: OR = odds ratio; 95% CI = 95% confidence interval. The unadjusted and adjusted results of the primary logistic regression analysis are shown comparing 30-day tracheostomy requirement of patients unable and able to move and hold against gravity with normal motor function within 24 h prior to extubation as assessed by the bedside nurse. After adjustment for confounding variables including sedation level, Acute Physiology and Chronic Health Evaluation II, CAM-ICU (Confusion Assessment Method for the Intensive Care Unit), and pre-defined predictors of extubation failure, the inability to hold against gravity was significantly associated with a higher requirement for 30-day tracheostomy compared to normal motor function.

Our findings demonstrate that the increase in tracheostomy risk with observed low motor function was magnified in younger patients and in patients with no history of congestive heart failure. Muscle strength decreases with age and is also lower in patients with heart failure.[1,24] In young patients with normal heart function, the observation of muscle weakness is expected less often and it may represent a more relevant predictor of tracheostomy in this patient population.

Muscle weakness in the ICU can be induced by several mechanisms.[25,26] Critically ill patients often acquire neuropathy and/or myopathy labeled as ICU-acquired weakness.[1] In addition, even in the absence of measurable nerve and muscle pathology, muscle atrophy and impairment of muscle contractility are common in the ICU as a result of sepsis, renal failure, or surgical trauma, which activates the inflammatory protein degradation pathway. Even in the absence of muscle atrophy, acute muscle weakness may be the consequence of electrolyte and acid-base imbalances, as well as impaired drive to skeletal muscle as a consequence of impaired arousal.[25,27] In our study, low GCS, deep sedation, and altered neurological condition during ICU admission were associated with a low SMART rating, implying that some of the muscle weakness reported by the nurses may be related to central arousal processes. Of note, even when adding GCS, sedation level and an underlying diagnosis of neurological dysfunction as confounding variables to the model, SMART rating explained significant variance in 30-day tracheostomy risk. This is important as deep sedation by itself is associated with prolonged mechanical ventilation and weaning from the ventilator, as well as longer ICU length of stay and increased mortality.[28]

	Normal activity	Unable to hold against gravity	Adjusted absolute risk difference (95% CI)	Interaction
Main effect	207 / 3,028 (6.8%)	277 / 2,348 (11.8%)	2.8% (1.5, 4.1)	
Age				
Age ≥ 70 years	101 / 970 (10.0%)	126 / 1,016 (12.0%)	0.2% (-2.2, 2.6)	*p* < 0.001
Age < 70 years	106 / 2,058 (5.0%)	151 / 1,332 (11.3%)	4.1% (2.6, 5.7)	
Duration of mechanical ventilation (MV)				
MV > 7 days	14 / 106 (13.2%)	72 / 209 (34.5%)	21.8% (12.4, 31.2)	*p* = 0.015
MV ≤ 7 days	193 / 2,922 (6.6%)	205 / 2,139 (9.6%)	2.8% (1.4, 4.2)	
History of congestive heart failure				
Yes	55 / 538 (10.2%)	57 / 528 (10.8%)	0.4% (-2.6, 3.4)	*p* = 0.046
No	152 / 2,490 (6.1%)	220 / 1,820 (12.1%)	3.2% (1.8, 4.6)	

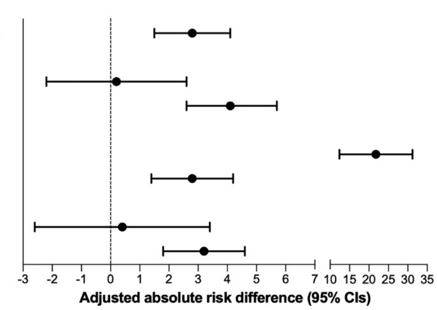

Figure 3. Effect modification. Abbreviations: CI = confidence interval. The adjusted absolute difference in tracheostomy risk (%) between patients unable to hold against gravity and those showing normal activity of extremities in the Subjective Motor Assessment RouTine (SMART) rating by the bedside nurse within 24 h prior to extubation was most noticeable among patients under the age of 70, patients without a history of congestive heart failure, and patients who received invasive mechanical ventilation for more than 7 days. The x-axis was rescaled above 10% in order to depict the whole range of adjusted absolute risk differences as listed in the reference table to the left of the diagram. Error bars representing the 95% confidence interval which include 0% (cross the vertical reference line) indicate no significant difference in tracheostomy risk between compared patient groups.

Table 2. Predictors of low SMART rating.

Variable of interest	Unable to hold against gravity (low SMART rating)	Odds ratio (95% confidence interval)
Glasgow Coma Scale (GCS), highest within 24 h prior to extubation		
GCS ≥ 13	202/1922 (10.5%)	1 - reference level
GCS ≤ 12	2144/7679 (27.9%)	3.30 (2.83-3.85), p < 0.001
Sedation level within 24 h prior to extubation		
RASS > 1	174/1272 (13.7%)	1 - reference level
RASS 0-1	888/3991 (22.3%)	1.80 (1.51-2.15), p < 0.001
RASS -1 and -2	831/3291 (25.3%)	2.13 (1.78-2.55), p < 0.001
RASS ≤ -3	455/1055 (43.1%)	4.79 (3.91-5.85), p < 0.001
Neurology as primary service of hospitalization		
no	2257/9366 (24.1%)	1 – reference level
yes	91/243 (37.5%)	1.89 (1.45-2.46), p < 0.001
APACHE II score		
APACHE II of 2-18 (Tertile 1)	784/3664 (21.4%)	1 – reference level
APACHE II of 19-23 (Tertile 2)	726/3041 (23.9%)	1.15 (1.03-1.29), p = 0.016
APACHE II of 24-47 (Tertile 3)	838/2904 (28.9%)	1.49 (1.33-1.67), p < 0.001
Duration of mechanical ventilation		
0-48 h	1635/7190 (22.7%)	1 – reference level
> 2 days	713/2419 (29.5%)	1.42 (1.28-1.57), p < 0.001
Any hyperkalemia within 24 h prior to extubation		
no	1703/7175 (23.7%)	1 – reference level
yes	645/2434 (26.5%)	1.16 (1.04-1.29), p = 0.006
Age		
18-69 years	1337/5843 (22.8%)	1 – reference level
70-99 years	1016/3766 (26.7%)	1.25 (1.14-1.38), p < 0.001
Hospital length of stay prior to extubation		
0-1 days (Tertile 1)	808/3525 (22.9%)	1 – reference level
2-4 days (Tertile 2)	719/3080 (23.3%)	1.02 (0.91-1.15), p = 0.69
5-180 days (Tertile 3)	820/3000 (27.3%)	1.26 (1.13-1.42), p < 0.001
ICU length of stay prior to extubation		
0-2 days	1576/6796 (23.2%)	1 – reference level
3-29 days	772/2813 (27.4%)	1.25 (1.13-1.38), p < 0.001

APACHE II = Acute Physiology and Chronic Health Evaluation; ICU = intensive care unit; RASS = Richmond Agitation-Sedation Scale; SMART = Subjective Motor Assessment RouTine.
Univariate logistic regression analysis was performed to evaluate binary and categorical variables of interest individually in their ability to predict the outcome "unable to hold against gravity" (ie a low SMART rating by the bedside nurse). The following variables did not significantly predict a low SMART rating in univariate logistic regression analysis: any hypokalemia, hypoxemia, hypercarbia, or acidosis within 24 h prior to extubation, admission to the hospital from a long-term care or skilled nursing facility, cumulative vasopressor dose within 24 h prior to extubation, non-depolarizing neuromuscular blockade within 24 h prior to extubation, lowest hemoglobin within 24 h prior to extubation.

ICU healthcare providers of different professions have differing perspectives on what constitutes a "weak patient".[29] It is likely that the nursing assessors did not rigorously measure muscle strength, but integrated muscle weakness and lack of endurance into their subjective assessments.[30] Our data show that this subjective impression by the bedside nurse, despite lack of standardized technique, explains variance of an important outcome measurement.

Clinical implications. It is recommended that motor strength and/or motor response of all critically ill patients should be assessed on a regular basis.[31] Our study emphasizes the value of subjective assessments of muscle function by ICU nurses. The rounding team needs to consider that the nurses' conclusion as to whether their patient is weak today needs to be integrated in the decision-making plan.

Nurses spend the most time at the bedside with the same patient, which may lead to a unique awareness of their patient's constitution, which in turn might allow them to notice the slightest changes. Previous research has demonstrated the ability of ICU nurses to accurately anticipate and predict survival and functional outcomes of patients.[32,33] Compared with predictive models limited to objective clinical measures, models that include subjective nurse and physician predictions had significantly higher discriminative accuracy for the patient outcomes.[32] Our findings demonstrate the importance of the subjective motor assessment performed by the bedside nurse, which should be taken into consideration during interdisciplinary rounds and decision-making in the ICU.

Limitations. The observational nature of retrospective design, including the use of data obtained from electronic medical records and administrative databases, confers the risk of unidentified, residual confounding. We adjusted our analyses for a wide range of potential confounding variables with good model performance and conducted several sensitivity analyses that confirmed the robustness of our findings. The decision to perform tracheostomy was not protocolized and therefore we cannot exclude that tracheostomy was performed in the weakest patients.

In conclusion, the subjective assessment of muscle function by critical care nurses adds important information to predict 30-day tracheostomy risk. The result was independent of patients' sedation level (RASS), delirium risk assessment (CAM-ICU), and severity of illness assessment (APACHE II). Our data emphasize the importance of interprofessional communication and cooperation in the ICU.

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Not applicable, because this article does not contain any studies with human or animal subjects.

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Supplemental Material

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