JAMA Otolaryngology–Head & Neck Surgery | Original Investigation

Endotracheal Tube Size in Critically Ill Patients

Brandon I. Esianor, MD; Benjamin R. Campbell, MD; Jonathan D. Casey, MD; Liping Du, PhD; Adam Wright, PhD; Bryan Steitz, PhD; Matthew W. Semler, MD; Alexander Gelbard, MD

IMPORTANCE Many patients who survive critical illness are left with laryngeal functional impairment from endotracheal intubation that permanently limits their recovery and quality of life. Although the risk for laryngeal injury increases with larger endotracheal tube sizes, there are no data delineating the association of smaller endotracheal tube sizes with survival or acute recovery from critical illness.

OBJECTIVE To determine if smaller endotracheal tubes are noninferior to larger endotracheal tubes with respect to critical illness outcomes.

DESIGN, SETTING, AND PARTICIPANTS This propensity score-matched retrospective cohort study included all adult patients who underwent endotracheal intubation in the emergency department or intensive care unit and received mechanical ventilation for at least 12 hours from June 2020 to November 2020 at a single tertiary referral academic medical center.

EXPOSURES Endotracheal intubation.

MAIN OUTCOMES AND MEASURES Propensity score-matched analyses were performed with respect to the primary end point of 30-day all-cause in-hospital survival as well as the secondary end points of duration of invasive mechanical ventilation, length of hospital stay, mean peak inspiratory pressure, 30-day readmission, need for reintubation, and need for tracheostomy or gastrostomy tube placement.

RESULTS Overall, 523 participants (64%) were men and 291 (36%) were women. Of these, 814 patients were categorized into 3 endotracheal tube groups: small for height (n = 182), appropriate for height (n = 408), and large for height (n = 224). There was not a significant difference in 30-day all-cause in-hospital survival between groups ([HR, 1.1; 95% CI, 0.7-1.7] for small vs appropriate; [HR, 1.1; 95% CI, 0.7-1.6] for large vs appropriate). Patients with small-for-height endotracheal tubes had longer intubation durations (mean difference, 32.5 hrs [95% CI, 6.4-58.6 hrs]) compared with patients with appropriate-for-height tubes.

CONCLUSIONS AND RELEVANCE Despite differences in intubation duration, the results of this cohort study suggest that smaller endotracheal tube sizes are not associated with impaired survival or recovery from critical illness. They support future prospective exploration of the association of smaller endotracheal tube sizes with recovery from critical illness.

JAMA Otolaryngol Head Neck Surg. 2022;148(9):849-853. doi:10.1001/jamaoto.2022.1939
Published online July 28, 2022.

Multimedia

Supplemental content

Author Affiliations: Department of Otolaryngology–Head and Neck Surgery, Vanderbilt University Medical Center, Nashville, Tennessee (Esianor, Campbell, Gelbard); Division of Allergy, Pulmonary, and Critical Care Medicine, Vanderbilt University Medical Center, Nashville, Tennessee (Casey, Semler); Department of Biostatistics, Vanderbilt University Medical Center, Nashville, Tennessee (Du); Department of Biomedical Informatics, Vanderbilt University Medical Center, Nashville, Tennessee (Wright, Steitz).

Corresponding Author: Alexander Gelbard, MD, 1215 21st Ave S, Nashville, TN 37232 (alexander.gelbard@vumc.org).

Tracheal intubation is a potentially life-saving procedure for critically ill patients. Yet up to 57% of critically ill patients intubated for longer than 12 hours develop mucosal injury in their proximal airway.[1] Such injury is associated with persistent dyspnea months after extubation.[1,2] The size of the endotracheal tube (ETT) is related to the risk of developing acute laryngeal injury—with larger ETT sizes, especially those larger than 7.0 mm, associated with greater risk.[1] Most ETTs placed in the setting of critical illness have an internal diameter of at least 7.5 mm, which prioritizes low airflow resistance, low risk of obstruction, and access for suction and bronchoscope devices.[3]

Although height is the primary determinant of airway size,[4] no clear guidelines exist for ETT size selection in adults. Historically, ETT size selection has been driven by the premise that smaller ETTs impair acute recovery from critical illness, but rigorous data supporting this belief is lacking. One recent study showed that almost 1 in 4 patients who underwent endotracheal intubation were intubated with an inappropriately large ETT (≥1.0 mm larger than recommended based on patient height).[5] It has been hypothesized that the use of smaller ETTs may be associated with better laryngeal functional outcomes among survivors of critical illness, but the effect of ETT size on early outcomes of mechanical ventilation for critical illness are relatively unknown.

We performed a retrospective, propensity score-matched (PSM) analysis to test the hypothesis that use of smaller ETTs would be noninferior to use of larger ETTs for mechanically ventilated intensive care unit (ICU) patients with respect to the primary end point of 30-day all cause in-hospital survival (defined as the days from intubation to death), as well as the secondary end points of duration of invasive mechanical ventilation, length of hospital stay, mean peak inspiratory pressure, 30-day readmission, need for reintubation, and need for tracheostomy or gastrostomy tube. The ETT size groups were standardized by patient height (small, appropriate, and large-for-height) to account for intrinsic patient characteristics that affect ETT size selection.

Key Points

Question Is the size of the endotracheal tube relative to patient height associated with survival and other critical care outcomes?

Findings In this propensity-score matched retrospective cohort study of 814 patients, there was no significant difference in 30-day all-cause in-hospital survival between patients with small, appropriate, or large-for-height endotracheal tubes. Patients with small-for-height tubes had longer intubation durations.

Meaning These results, when paired with prior studies, suggest that smaller endotracheal tubes are not associated with impaired recovery from critical illness and are better for overall laryngeal health.

Methods

Design and Study Population

Following approval from the Vanderbilt University institutional review board (210078), we performed a retrospective cohort study of all adult patients who underwent endotracheal intubation in the emergency department (ED) or ICU and received mechanical ventilation for at least 12 hours at a single academic medical center from June 2020 to November 2020. Written informed consent was waived owing to the retrospective nature of the data used. In both the ED and ICUs, Shiley Hi-Lo Oral/Nasal, Cuffed, Intermediate, Murphy Eye ETTs were used for intubation. The corresponding inner diameter (ID) and outer diameter (OD) of these ETTs are as follows: 6.5/8.9; 7.0/9.5; 7.5/10.2; 8.0/10.8 (ID/OD [mm]). The ETTs with the above-the-cuff suction port feature were not routinely used at the study hospital. All data were extracted from the institutions' Epic Clarity data warehouse. Exclusion criteria included intubation duration of less than 12 hours, obstructive airway masses, and missing study data (eg, height, ETT size). For different end points and comparisons, further exclusions of patients were applied when appropriate (eTables 1 and 2 in the Supplement).

Evaluating ETT Size Selection

Drawing from the established nomogram,[5] the ideal ETT size was defined as 7.0-mm internal diameter for those with a height of 160 cm or shorter, 7.5 mm for those with a height between 161 cm and 179 cm, and 8.0 mm for those with a height of 180 cm or taller (**Figure**, A). By comparing the ETT used for intubation (ETT_{used}) and the ideal ETT (ETT_{ideal}), each patient was categorized as either having a small-for-height ($ETT_{used} < ETT_{ideal}$, "small"), appropriate-for-height ($ETT_{used} = ETT_{ideal}$, "appropriate"), or large-for-height ETT ($ETT_{used} > ETT_{ideal}$, "large").

Outcomes

The primary study end point was 30-day all-cause in-hospital mortality, which was defined as the days from intubation to death. Censoring events were the first of next intubation, discharge, or 30 days.

Secondary end points included duration of invasive mechanical ventilation, mean peak inspiratory pressure, need for reintubation within 14 days in-hospital, duration of hospital stay for those who survived to discharge, need for tracheostomy or gastrostomy tube for those survived to discharge, bronchoscopy during intubation, ventilator-associated pneumonia (VAP), and 30-day readmission after discharge.

Statistical Analysis

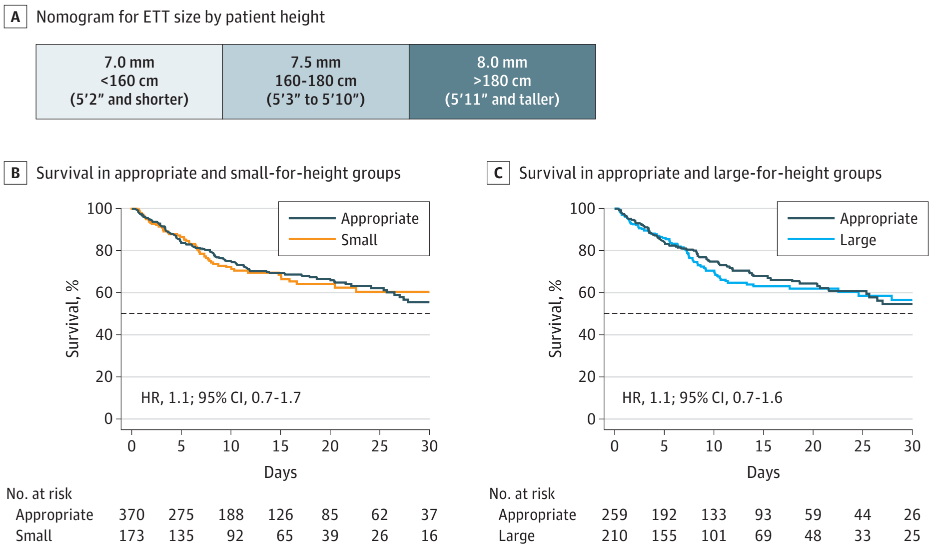
Propensity score matching (1:1 nearest neighbor matching) was used to compare outcomes between the 3 ETT groups: small, appropriate, and large. Subgroup analysis was also performed for those with a respiratory admission diagnosis. Covariates included in the propensity score models were sex, height, body mass index (BMI, calculated as weight in kilograms divided by height in meters squared), admission diagnosis (trauma, respiratory, neurologic, cardiac, gastrointestinal, or other), and location of intubation (ED or ICU). After matching, Cox regression, linear regression, or logistic regression was performed on the matched data for survival, continuous, or binary outcome, respectively. Results were reported using an effect size metric (eg, odds ratio [OR], hazard ratio [HR], mean difference) paired with 95% CIs to describe the precision of the estimate. All statistical analyses were completed using R (version 4.1.1; R Core Team, 2021).

Results

A total of 814 patients who underwent tracheal intubation met eligibility criteria and were included in the current analyses (**Table 1**). Most included patients were male (523 [64%]) with a median BMI of 27.3 (interquartile range [IQR], 23.6 to 33.1). Intubating clinicians were primarily critical care (37%) and emergency medicine (37%) followed by anesthesia (25%). Admitting diagnosis was classified as either trauma (174 [21%]), respiratory (170 [21%]), neurologic (193 [24%]), cardiac (61 [7%]), gastrointestinal (57 [7%]), or other (159 [20%]). The distribution of ETT sizes was as follows: 6.5 or smaller (n = 8), 7.0 (n = 86), 7.5 (n = 431), and 8.0 (n = 289). Comparison of the ETT sizes used in this cohort with a 372-patient cohort from 1985[6] suggests a subtle but significant shift toward the use of smaller ETTs in critical care medicine over the past 40 years (mean ETT size, 8.06 [1985] vs 7.61 [2020]; mean difference, 0.45; 95% CI, 0.33-0.55) (eFigure in the Supplement).

Based on the relationship of ETT_{used} and ETT_{ideal}, 182 patients (22.4%) were categorized into the small ETT group, 408 (50.1%) into the appropriate ETT group, and 224 (27.5%) into the large ETT group. Patients with small ETTs were more likely to have been intubated by an attending physician (95 participants [74%] in the ETT group were intubated by attending physician with a small vs 177 [58%] with an appropriate vs 102

Figure. 30-Day Overall In-Hospital Survival by Endotracheal Tube (ETT) Size Group



A, Nomogram indicating appropriate ETT size by patient height.
B, Kaplan-Meier curves for appropriate and small-for-height ETT selection groups before matching.
C, Kaplan-Meier curves for appropriate and large-for-height ETT selection groups before matching.

Table 1. Overall Cohort Characteristics

Measure	No. (%) Total cohort (n = 814)	Appropriate for height (n = 408)	Large for height (n = 224)	Small for height (n = 182)
Sex				
Male	523 (64)	248 (61)	141 (63)	134 (74)
Female	291 (36)	160 (39)	83 (37)	48 (26)
Height, median (IQR), cm	173 (165-180)	173 (165-183)	168 (158-175)	183 (171-183)
BMI, median (IQR)	27.3 (23.6-33.1)	27.5 (23.7-33.2)	27.7 (23.5-33.9)	27 (23.9-30.7)
Intubation location				
ED	354 (43)	187 (46)	75 (33)	92 (51)
ICU	460 (57)	221 (54)	149 (67)	90 (49)
Training				
Attending	374 (62)	177 (58)	102 (59)	95 (74)
Fellow	103 (17)	57 (19)	36 (21)	10 (8)
Resident	129 (21)	71 (23)	34 (20)	24 (19)
Specialty				
Anesthesia	129 (25)	57 (22)	33 (23)	39 (34)
Critical care	192 (37)	103 (41)	64 (44)	25 (22)
Emergency medicine	192 (37)	94 (37)	48 (33)	50 (44)
Admission diagnosis				
Trauma	174 (21)	88 (22)	35 (16)	51 (28)
Respiratory	170 (21)	87 (21)	53 (24)	30 (16)
Neurologic	193 (24)	108 (26)	48 (21)	37 (20)
Cardiac	61 (7)	27 (7)	20 (9)	14 (8)
Gastrointestinal	57 (7)	27 (7)	19 (8)	11 (6)
Other	159 (20)	71 (17)	49 (22)	39 (21)

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); ED, emergency department; ICU, intensive care unit.

[59%] with a large ETT). Patients intubated with large ETTs were more likely to be intubated in the ICU (90 participants [49%] in the ETT group intubated in ICU with a small vs 221 [54%] with an appropriate vs 149 [67%] with a large ETT). Overall rates of bronchoscopy and VAP in the total cohort were relatively low, at 10% and 5.9%, respectively.

The difference in 30-day all-cause in-hospital mortality between small and appropriate ETT groups was small and no definitive conclusions can be made given the width of the CI (173 PSM pairs; HR, 1.1; 95% CI, 0.7-1.7) (Figure, B). In the secondary end point analysis, patients with small ETTs had a longer duration of intubation (mean difference, 32.5 hours; 95% CI, 6.4-58.6). The differences in hospital stay (mean difference, 3.5 days; 95% CI, −0.04 to 7.1) and peak inspiratory pressure (PIP) (mean difference, 1.1 cm H_2O; 95% CI, −0.2 to 2.4) between small and appropriate ETT groups were moderate but the width of the CIs prevents definitive conclusions from being drawn. There were no clinically meaningful differences in the

Table 2. Outcome Results Comparing Small and Appropriate Endotracheal Tube (ETT) Size Groups

Variable	PS-matched pairs, No.	Effect measure	Estimated effect size (95% CI)[a]
Primary end point			
30-d in-hospital overall survival	173	HR	1.1 (0.7 to 1.8)
Secondary end points			
30-d readmission after discharge	105	OR	1.02 (0.93 to 1.11)
Tracheostomy at discharge or death among those survived to discharge	108	OR	1.1 (0.9 to 1.2)
PEG at discharge or death among those survived to discharge	108	OR	1.05 (0.97 to 1.13)
Reintubation within 14 d in hospital after index extubation among those survived to discharge	106	OR	0.95 (0.85 to 1.07)
Duration of intubation among those survived to hospital discharge, h	108	Mean difference	32.5 (6.4 to 58.6)
Average PIP during intubation, cm H_2O	178	Mean difference	1.1 (−0.2 to 2.4)
Length of hospital stay among those survived to discharge, d	108	Mean difference	3.5 (−0.04 to 7.1)
Bronchoscopy while intubated	180	OR	0.96 (0.90 to 1.03)
Ventilator-associated pneumonia	180	OR	0.99 (0.94 to 1.05)

Abbreviations: HR, hazard ratio; OR, odds ratio; PEG, percutaneous endoscopic gastrostomy; PIP, peak inspiratory pressure; PS, propensity score.

[a] Reference group for comparison: appropriate for height ETT group.

Table 3. Outcome Results Comparing Large and Appropriate Endotracheal Tube (ETT) Size Groups

Variable	PS matched pairs, No.	Effect measure	Estimated effect size (CI)[a]
Primary end point			
30-d in-hospital overall survival	210	HR	1.1 (0.8 to 1.6)
Secondary end points			
30-d readmission after discharge	139	OR	1.04 (0.96 to 1.13)
Tracheostomy at discharge or death among those survived to discharge	144	OR	1.0 (0.9 to 1.1)
PEG at discharge or death among those survived to discharge	144	OR	0.98 (0.95 to 1.02)
Reintubation within 14 d in hospital after index extubation among those survived to discharge	140	OR	0.98 (0.89 to 1.07)
Duration of intubation among those survived to hospital discharge, h	144	Mean difference	4.5 (−17.7 to 26.7)
Average PIP during intubation, cm H_2O	222	Mean difference	−0.3 (−1.5 to 0.9)
Length of hospital stay among those survived to discharge, d	144	Mean difference	1.2 (−1.9 to 4.4)
Bronchoscopy while intubated	222	OR	0.96 (0.91 to 1.02)
Ventilator-associated pneumonia	222	OR	0.97 (0.93 to 1.02)

Abbreviations: HR, hazard ratio; OR, odds ratio; PEG, percutaneous endoscopic gastrostomy; PIP, peak inspiratory pressure; PS, propensity score.

[a] Reference group for comparison: appropriate for height ETT group.

remaining secondary end points between these groups (**Table 2**).

The difference in the 30-day all-cause in-hospital mortality between the large and appropriate ETT groups was small, and no definitive conclusions can be made given the width of the CI (210 PSM pairs; HR, 1.1; 95% CI, 0.7-1.6) (Figure, C). There were no clinically meaningful differences in any secondary end points between these 2 groups (**Table 3**).

The difference in the 30-day all-cause in-hospital mortality between small and large ETT groups was small, and no definitive conclusions can be made given the width of the CI (55 PSM pairs, HR, 1.2; 95% CI, 0.6-2.8). Similar to these analyses, patients with small ETTs had a longer duration of intubation (mean difference, 45.2 hours; 95% CI, 6.2-84.1) when compared with those with large ETTs. Patients with small ETTs also had increased rates of percutaneous endoscopic gastrostomy (PEG) tube placement (OR, 1.18; 95% CI, 1.03-1.37). There were no other clinically meaningful differences in the remaining secondary end points between these groups (eTable 3 in the Supplement).

For patients with a respiratory admission diagnosis, there was no clinically meaningful difference in 30-day all-cause in-hospital mortality between any of the 3 ETT groups. There was also no clinically meaningful difference in any of the additional secondary outcome analyses that were able to be performed (eTable 4 in the Supplement).

Discussion

Historically, each year in the US, 2 to 3 million adults experience critical illness requiring tracheal intubation.[7,8] In addition, the demand for intensive respiratory support has dramatically increased during the SARS-CoV-2 pandemic.[9] Prior research suggests that many of these patients will experience long-term morbidity from a type of laryngeal injury that is closely linked to endotracheal tube size, but many patients continue to receive large ETTs based on concerns that small ETTs may prevent ventilator weaning and recovery.

Using the height-based ETT selection nomogram, our data showed that 224 patients (27.5%) intubated for critical illness received an inappropriately large ETT. Compared with patients who received an appropriate ETT, patients with small ETTs did not demonstrate worse overall 30-day survival. However, patients with small ETTs did have a longer duration of intubation, but this did not result in higher rates of tracheostomy, reintubation, VAP, or prolonged hospital stay. In addition, large-for-height ETTs was not associated with any survival advantage or improvement in other respiratory and critical care metrics. Bronchoscopy rates (10%) were low across the cohort, and patients with small ETTs did not demonstrate an increased rate of bronchoscopy.

Although the effect of appropriate ETT size on critical care outcomes is a relatively understudied question, a few groups have investigated the association of tube size with ventilator weaning and respiratory mechanics.[10-12] Overall, it has been shown that smaller diameter ETTs are associated with an increase in various respiratory metrics, including airway pressures and respiratory frequency to tidal volume ratios.[10-12] The effect of tube diameter on these metrics may be the driver behind the increased intubation duration noted in our study, although we did not observe a significant relationship between ETT size group and PIP.

To date, there are not widely adopted guidelines for ETT size selection in the critical care community. Historically, an 8.0 ETT was the standard selection for males, whereas a 7.0 was common for females. However, recent studies have demonstrated that rather than being purely influenced by sex, height was a stronger predictor of airway diameter.[4,5] Despite this knowledge, 20% to 30% of patients are intubated with large ETTs, and more work is needed to establish universal guidelines for ETT size selection.

Limitations

Although our EMR data collection tool was successful in capturing intubation events across the health care system, it was unable to gather certain metrics, such as overall illness severity score and tube exchange events. Lack of an overall illness severity score, such as Charlson Comorbidity Index or Acute Physiology and Chronic Health Evaluation, is a potential limitation of our study and could be a confounder given that patients with large ETTs were more likely to be intubated in the ICU. Despite lacking information on tube exchange rate, 2 surrogate metrics (72-hour reintubation and rapid response rates) were low (11.8% and 5.7%, respectively) in the overall cohort and did not differ by ETT size group. Therefore, we suspect the need to upsize to a larger ETT was low in our cohort. Prospectively delineating the rate of tube exchange when small-for-height ETTs are used remains an important question for future research.

Conclusions

During intubation, critical care professionals balance the postulated benefits of larger ETTs on survival with the negative effects of larger ETTs on laryngeal function. The results of this cohort study suggest that smaller ETTs may not impair recovery from critical illness, whereas larger ETTs may not confer a benefit. Furthermore, this study provides the foundation for future work investigating the use of smaller endotracheal tubes with the goal of minimizing acute laryngeal injury, optimizing postextubation laryngeal function, and maximizing the quality of life lived after critical illness.

ARTICLE INFORMATION

Accepted for Publication: June 5, 2022.

Published Online: July 28, 2022. doi:10.1001/jamaoto.2022.1939

Author Contributions: Drs Esianor and Gelbard had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs Esianor and Campbell contributed equally to this work and are co–first authors.
Concept and design: Esianor, Casey, Du, Wright, Semler, Gelbard.
Acquisition, analysis, or interpretation of data: Esianor, Campbell, Casey, Du, Wright, Steitz, Gelbard.
Drafting of the manuscript: Esianor, Campbell, Du, Gelbard.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Campbell, Du, Gelbard.
Obtained funding: Gelbard.
Administrative, technical, or material support: Esianor, Casey, Wright, Steitz, Gelbard.
Supervision: Esianor, Casey, Semler, Gelbard.

Conflict of Interest Disclosures: Dr Casey reported grants from NIH K23HL153584 and grants from Department of Defense outside the submitted work. No other disclosures were reported.

REFERENCES

1. Shinn JR, Kimura KS, Campbell BR, et al. Incidence and outcomes of acute laryngeal injury after prolonged mechanical ventilation. *Crit Care Med*. 2019;47(12):1699-1706. doi:10.1097/CCM.0000000000004015

2. Brodsky MB, Levy MJ, Jedlanek E, et al. Laryngeal injury and upper airway symptoms after oral endotracheal intubation with mechanical ventilation during critical care: a systematic review. *Crit Care Med*. 2018;46(12):2010-2017. doi:10.1097/CCM.0000000000003368

3. Karmali S, Rose P. Tracheal tube size in adults undergoing elective surgery—a narrative review. *Anaesthesia*. 2020;75(11):1529-1539. doi:10.1111/anae.15041

4. Coordes A, Rademacher G, Knopke S, et al. Selection and placement of oral ventilation tubes based on tracheal morphometry. *Laryngoscope*. 2011;121(6):1225-1230. doi:10.1002/lary.21752

5. Cao AC, Rereddy S, Mirza N. Current practices in endotracheal tube size selection for adults. *Laryngoscope*. 2021;131(9):1967-1971. doi:10.1002/lary.29192

6. Gaynor EB, Greenberg SB. Untoward sequelae of prolonged intubation. *Laryngoscope*. 1985;95(12):1461-1467. doi:10.1288/00005537-198512000-00005

7. Heidegger T. Management of the difficult airway. *N Engl J Med*. 2021;384(19):1836-1847. doi:10.1056/NEJMra1916801

8. Kempker JA, Abril MK, Chen Y, Kramer MR, Waller LA, Martin GS. The epidemiology of respiratory failure in the United States 2002-2017: a serial cross-sectional study. *Crit Care Explor*. 2020;2(6):e0128. doi:10.1097/CCE.0000000000000128

9. Ouyang L, Yu M, Zhu Y, Gong J. Respiratory supports of COVID-19 patients in intensive care unit: a systematic review. *Heliyon*. 2021;7(4):e06813. doi:10.1016/j.heliyon.2021.e06813

10. Karagiannidis C, Merten ML, Heunks L, et al. Respiratory acidosis during bronchoscopy-guided percutaneous dilatational tracheostomy: impact of ventilator settings and endotracheal tube size. *BMC Anesthesiol*. 2019;19(1):147. doi:10.1186/s12871-019-0824-5

11. Mehta S, Heffer MJ, Maham N, Nelson DL, Klinger JR, Levy MM. Impact of endotracheal tube size on preextubation respiratory variables. *J Crit Care*. 2010;25(3):483-488. doi:10.1016/j.jcrc.2009.11.005

12. Valentini I, Tonveronachi E, Gregoretti C, et al. Different tracheotomy tube diameters influence diaphragmatic effort and indices of weanability in difficult to wean patients. *Respir Care*. 2012;57(12):2012-2018. doi:10.4187/respcare.01747