Disposable Bronchoscopy in Airway & Ventilation Management: From the OR to the ICU

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Disclosures

Nicole Bennett BSRT, RRT, RRT-ACCS, Bridget Berns BS, RN, Michael Boyle BSN, RN and Loren Gant BBA, BSN are clinical specialists employed by TSC Endovision.

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Course Objectives

- Identify the disposable bronchoscopes on the market including similarities, differences, and appropriate use
- Identify and understand the effects of intubation on the airway
- Identify and understand the effects of bronchoscopy in mechanically ventilated patients
- Understand the relationship between ETT size and bronchoscope size
- Prevent patient injury by recommending or selecting the correct size ETT and bronchoscope

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What are my options?

How do I choose?

Bronchoscopy Indications

Operating Room

- Airway inspection
- Difficult intubations
- DLT & ETT placement confirmation
- Foreign body removal
- Percutaneous tracheostomy
- Tissue sample collection

Intensive Care Units

- Airway inspection
- BAL & bronchial washout
- Difficult intubations
- Foreign body removal
- Percutaneous tracheostomy
- Tissue sample collection

What do all disposable bronchoscopes have in common?

Camera with light source

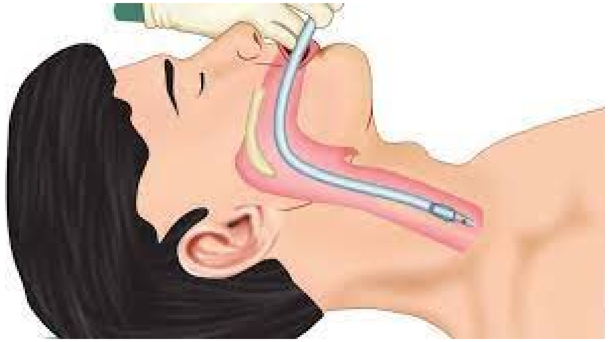
Suction connection

Working channel

Viewing monitor

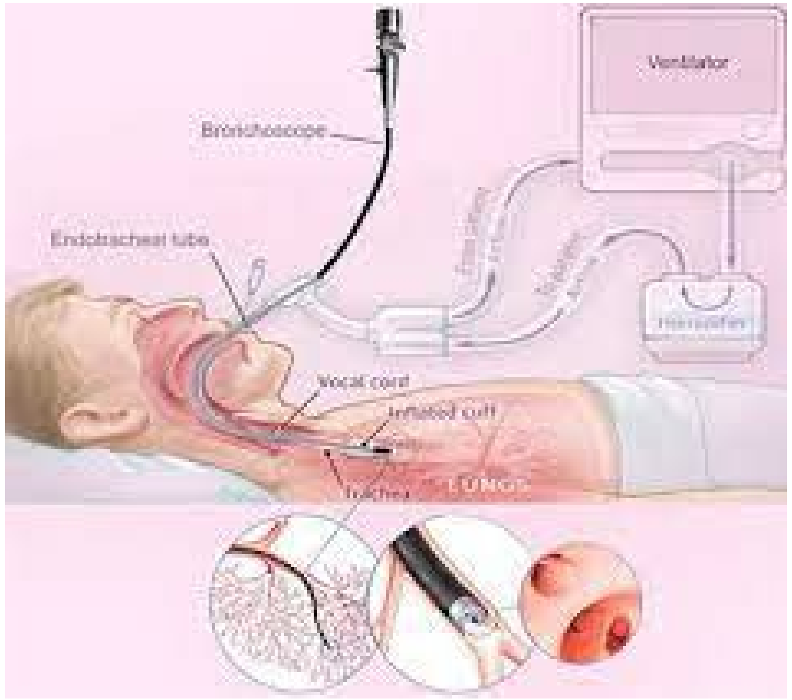
If they are all basically the same, then why does it matter?

Two main considerations



Effects of intubation on the airway

Effects of bronchoscopy in mechanical ventilation



Airway Complications of Intubation

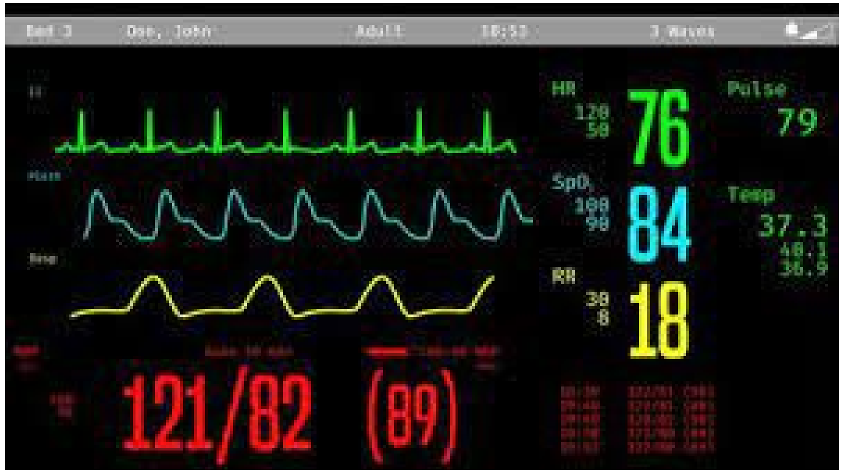
- Airway Stenosis
- Aspiration
- Dislocation of tracheal cartilage
- Extubation failure
- Hoarseness
- Injury to tongue, lips, and teeth
- Laryngospasms
- Sore throat
- Speech/swallowing impairments
- Upper airway obstruction due to edema and inflammation
- Vocal cord damage (granulomas, ulceration, and paralysis)

Damage to the airway can occur with an ETT in place for as little as one or two hours[1]

[1]Brodsky, M. B., Akst, L. M., Jedlanek, E., Pandian, V., Blackford, B., Price, C., Cole, G., Mendez-Tellez, P. A., Hillel, A. T., Best, S. R., & Levy, M. J. (2020). Laryngeal Injury and Upper Airway Symptoms After Endotracheal Intubation During Surgery: A Systematic Review and Meta-analysis. *Anesthesia & Analgesia*, *132*(4), 1023–1032. https://doi.org/10.1213/ane.0000000000005276

Potential Bronchoscopy Complications

- Barotrauma
- Bronchospasm
- Cardiac arrhythmias
- Hemorrhage
- Hypotension
- Hypoxemia
- Increased BP and HR
- Infection
- Laryngospasm
- Pneumothorax



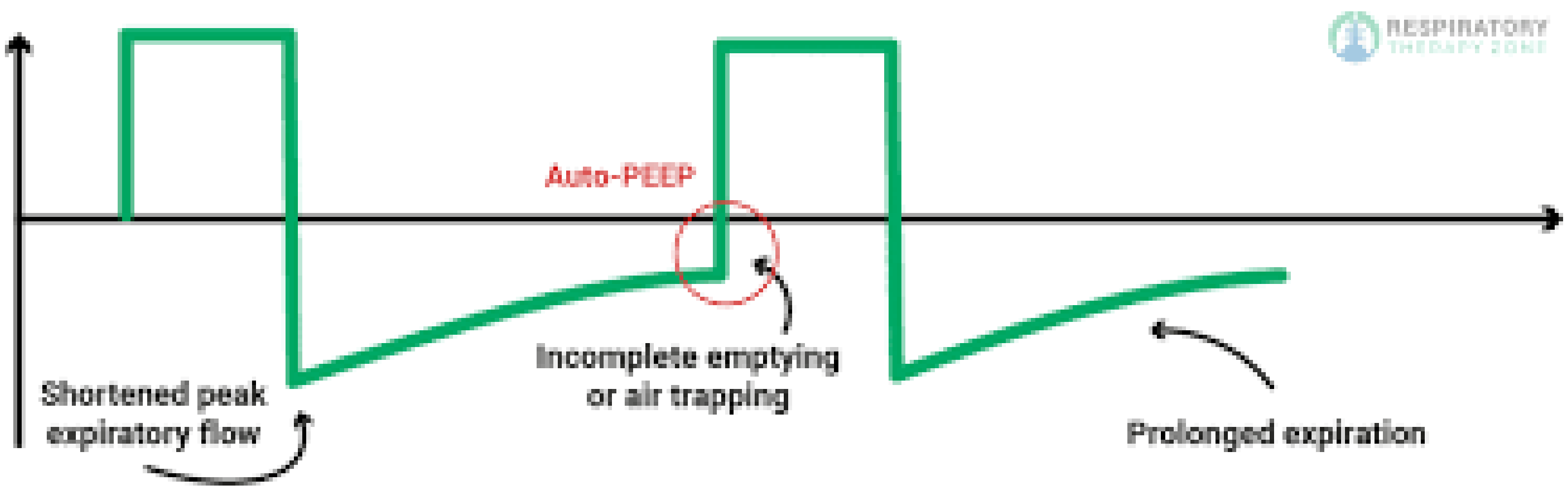
Ventilator Pressures to Consider

PEEP = Positive End of Expiration Pressure

- Pressure applied at the end of the expiration phase to prevent atelectasis, keep the alveoli open, and improve oxygenation

Auto-PEEP = PEEP due to airway resistance

- Incomplete exhalation of tidal volumes leading to air trapping, "breath stacking", and CO_2 retention



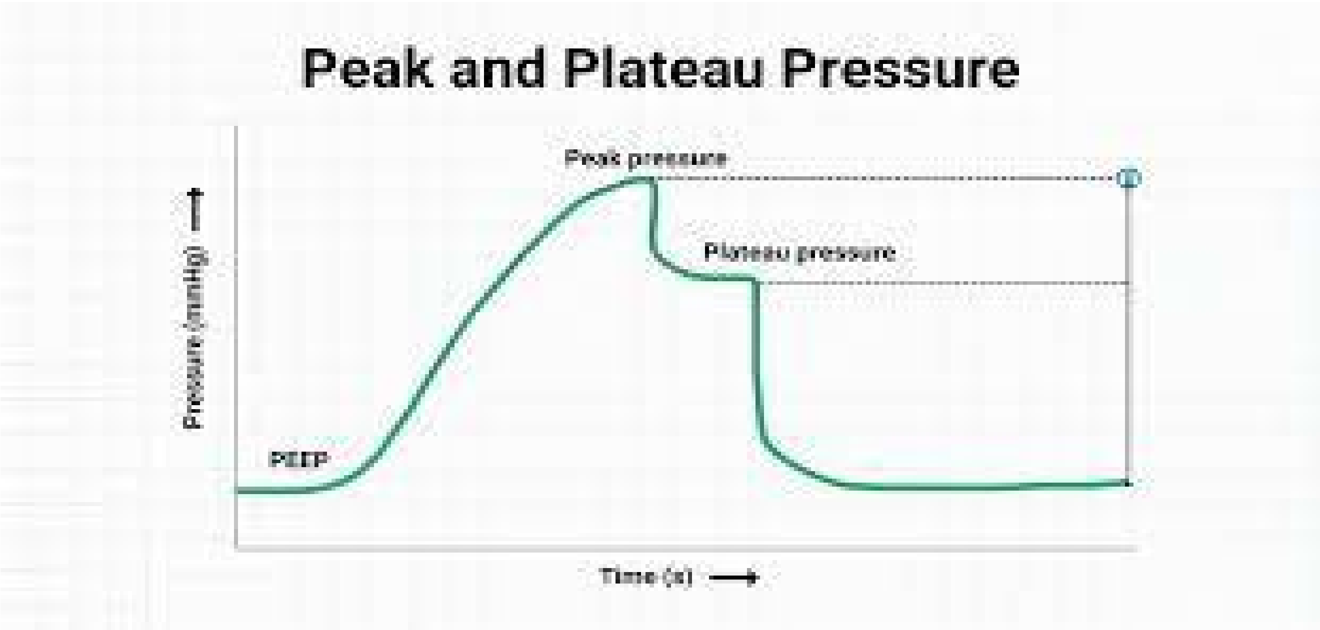
Ventilator Pressures to Consider

Peak pressure = highest pressure delivered by the ventilator

- Pressure generated by the ventilator to overcome airway and alveolar resistance and deliver a desired tidal volume; airflow in the circuit

Plateau Pressure = pressure at the end of inspiratory hold

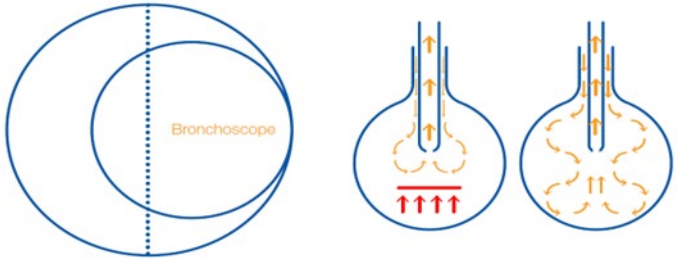
- Pressure that remains in the lungs after a tidal volume breath has been delivered; no airflow in the circuit



Effects of Bronchoscopy in Mechanical Ventilation

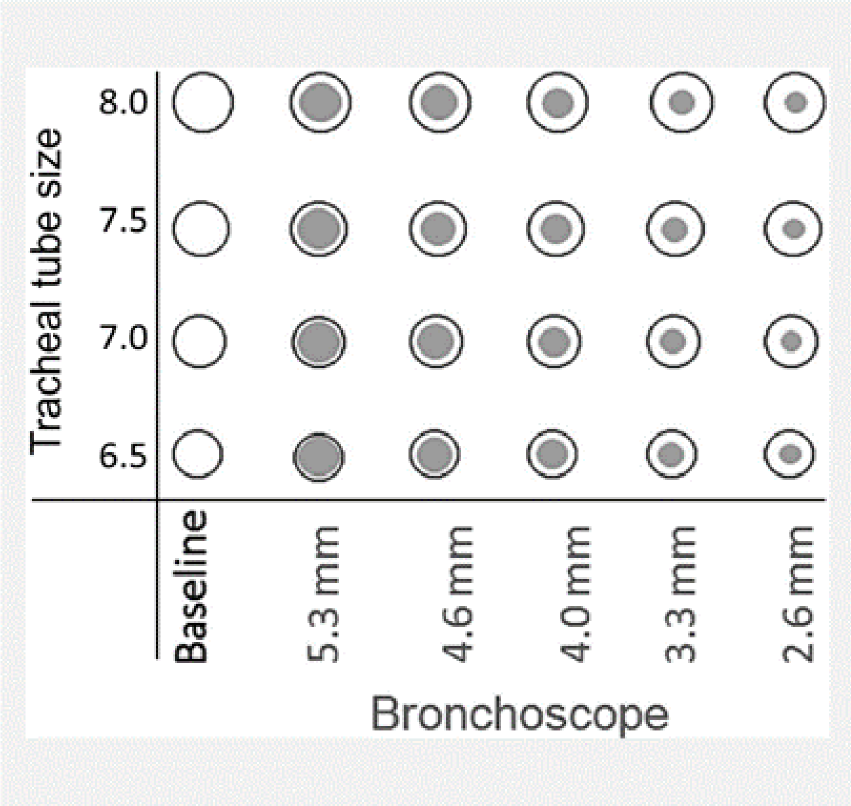
There are several consequences of inserting a bronchoscope through an ETT

- Decreased tidal volume
- Increased airway resistance
- Vacuum due to suction=Atelectasis
- Loss of PEEP=Hypoxemia



• Cross-section of an endotracheal tube

Effects of Bronchoscopy in Mechanical Ventilation



- Incompletely exhaled tidal volumes due to increased airway resistance = **risk of increased intrathoracic pressure/barotrauma**
- Total-PEEP and the Pplat increase immediately following insertion of a bronchoscope[2]
- Bronchoscopes with a wide suction channel are usually required for patients who are supported by mechanical ventilation in intensive care units

[2] Nay MA, Mankikian J, Auvet A, Dequin PF, Guillon A. The effect of fibreoptic bronchoscopy in acute respiratory distress syndrome: experimental evidence from a lung model. Anaesthesia. 2016 Feb;71(2):185-91. doi: 10.1111/anae.13274. Epub 2015 Nov 12. PMID: 26559154.

Size Matters!

Choosing the right endotracheal tube/bronchoscope size

Table 1 Effect of introducing a 5.7-mm diameter bronchoscope into differently sized tracheal tubes.

	6.0 mm*	7.0 mm	8.0 mm	9.0 mm
Cross-sectional area of tube without bronchoscope; mm^2	28.3	38.5	50.3	63.6
Remaining tube area with bronchoscope in situ; mm^2	6.8	17.0	28.7	42.1
Proportion of tube cross-section area obstructed	76.0%	55.8%	42.9%	33.8%

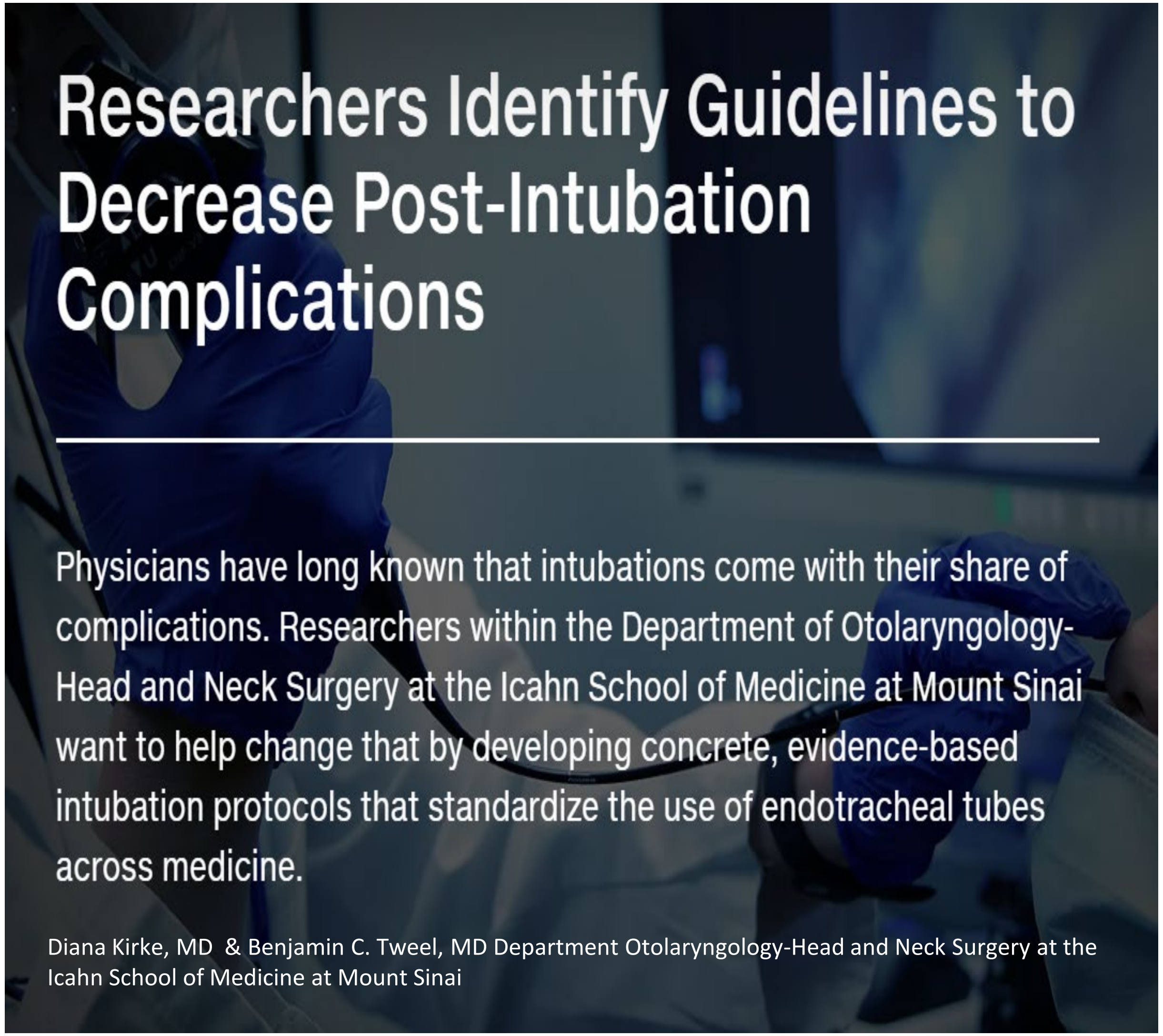
*a 5.7-mm bronchoscope cannot actually be inserted into a 6.0-mm tube.

[3] Farrow S, Farrow C, Soni N. Size matters: choosing the right tracheal tube. Anaesthesia. 2012 Aug;67(8):815-9. doi: 10.1111/j.1365-2044.2012.07250.x. PMID: 22775368

By introducing the bronchoscope into the ETT, it will occupy up to **66% of the diameter of ETT**[4]

[4]Patolia, S., Farhat, R., & Subramaniyam, R. (2021). Bronchoscopy in intubated and non-intubated intensive care unit patients with respiratory failure. *Journal of thoracic disease*, *13*(8), 5125–5134. https://doi.org/10.21037/jtd-19-3709

Size Matters!



- 386 patients who were intubated in the emergency room before the pandemic from 2018 to 2020
- 57% were intubated with an 8.0 ETT and 13% developed complications that needed further treatment
- 81% of the patients who had problems post-intubation were intubated with at least an 8.0 ETT

"It has generally been thought that larger intubation tubes improve ventilation because it is easier to pass a bronchoscopy through the airway and flush out the lungs, but smaller instruments are available today that can achieve this."

Size Matters!

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Journal of Anesthesia & Clinical Research

Commentary

Commentary on Current Practices in Endotracheal Tube Size Selection for Adults

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DISCRIPTION

Intubation with inappropriately sized Endotracheal Tubes (ETT) can cause complications including sore throat, hoarseness, vocal cord injury, acute laryngeal injury, and laryngotracheomalacia [1-3]. As no widely accepted guidelines currently exist for determining appropriate ETT size in adults, practitioners often rely on heuristics and clinical judgment. There is increasing evidence that tracheal dimensions are correlated with patient characteristics such as height and sex; however it remains unclear if this data is being incorporated into clinical practice.

We recently published a retrospective cohort study designed to determine the rate of appropriate ETT size selection in adult patients at a large academic hospital [4]. To estimate the recommended endotracheal tube size for each patient, we used a height-based model derived from Coordes et al., which demonstrated a linear correlation between height, coronal subcricoid tracheal diameter, and distance between lower incisors and cricoid cartilage [5]. Our study demonstrated that height-based ETT size selection has yet to be widely implemented. 22% of our patients were intubated with an inappropriately large tube, which was defined as at least 1.0 mm larger than the recommended size. Female patients and patients with shorter height (<1.6 m) were significantly more susceptible to intubation with an inappropriately large ETT. We hypothesize that this may contribute to the increased rates of post-intubation tracheal stenosis in women [6,7].

In our study, providers across clinical settings defaulted to using a 7.0 mm ETT for female patients and an 8.0 mm for males. In the absence of widely disseminated guidelines, the increased rate of inappropriate ETT may be best explained by the sex-based heuristic sizing seen in our cohort. While it is clear that sex is a major determinant of tracheal dimensions, Coordes et al. showed that the difference in tracheal diameter between sexes vanished after controlling for patient height. Two other imaging studies in the literature stratified their patients by sex and do not discuss the role of patient height [8,9]. With these findings, we recommend that a size 6.0-6.5 endotracheal tube should be considered for females below average height (163 cm), and a size 7.0-7.5 should be considered for males below average height (177 cm). For females, ETT larger than 7.0 should only be used if adequate ventilation is not possible with a smaller tube.

There is also ongoing discussion about the role of BMI in ETT sizing. While there are anecdotal reports that providers tend to place larger ETT in obese patients, D'Anza demonstrates that BMI appears to be inversely related to tracheal width [9,10]. In our cohort, we did not find evidence of increased inappropriate ETT sizing in obese patients.

Finally, we hypothesized that practitioners may be more likely to select an inappropriately large ETT in severely ill patients, anticipating bronchoscopy or an increased sensitivity to changes in ventilation [11]. However, we did not find an association between inappropriate ETT sizing and disease severity risk factors, including setting of intubation, emergent intubation, elevated SAPS II, or requiring bronchoscopy during hospitalization. While providers likely consider these factors, our data indicates that other heuristics predominate in size selection, even in severely ill patients.

The primary barrier to implementation of standardized, height-based ETT size selection in adults is the lack of published guidelines. Once such guidelines are adopted and disseminated, simple interventions such as checklists or web-based training will be critical for standardizing the practice of height-based ETT size selection across institutions.

DISCUSSION AND CONCLUSIONS

We believe that our study highlights the following:

1. There is a need for intubating providers to shift from sex-based heuristics to height-based guidelines for endotracheal tube size selection in adults.
2. The rate of inappropriate ETT sizing was significantly higher in female patients and patients with shorter stature.
3. Size 6.0-6.5 ETT can be considered more often for females below average height, and 7.0-7.5 can be considered for males below average height.

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- Several recent studies support a height-based model of determining ETT size
- 22% of patients were intubated with an inappropriately large tube (at least 1.0 mm larger than the recommended size)
- Females and patients with shorter height (<1.6 m or 63 in) were significantly more susceptible to intubation with an inappropriately large ETT
  - ➢ **increased rates of post-intubation stenosis also noted in women**
- 6.0-6.5 ETT should be considered for females below average height (163 cm/64 in), and a size 7.0-7.5 should be considered for males below average height (177 cm/70 in)
- For females, ETT larger than 7.0 should only be used if adequate ventilation is not possible with a smaller tube

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.

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Size Matters!

- The size of the ETT is related to the risk of developing acute laryngeal injury
- Larger ETT sizes (>7.0) are associated with greater risk
- Most ETTs placed in the ICU have an internal diameter of at least 7.5 mm, which prioritizes low airflow resistance, low risk of obstruction, access for suction and bronchoscope devices
- Many patients continue to receive large ETTs based on concerns that small ETTs may prevent ventilator weaning and recovery
- Patients with small ETTs did not demonstrate worse overall 30-day survival rates
- Large-for-height ETTs were not associated with any survival advantage or improvement in other respiratory and critical care metrics

Size Matters!

The Effects of Endotracheal Tube Size During Bronchoscopy in Simulated Models of Intubated Patients

Saveliy Kelebeyev, MD; Wesley Davison, MD; Branden L. Ford, BA; Michael J. Pitman, MD; William A. Bulman, MD

Objective: The aim is to use a simulation lung model to assess the possibility of performing bronchoscopy through endotracheal tubes (ETT) less than 8.0-mm while appropriately ventilating patients with normal and ARDS lungs in the setting of SARS-CoV-2.

Methods: Five SHERIDAN® ETTs were used to ventilate SimMan® 3G under respiratory compliance levels representing normal and severe ARDS lungs. Baseline measurements of peak pressure, plateau pressure, and auto-positive end expiratory pressure (auto-PEEP) were recorded at four different inspiratory times (Ti). Three different-sized disposable bronchoscopes were inserted, and all measurements were repeated.

Results: *Normal lung model:* Slim bronchoscopes in 6.0-mm ETTs resulted in plateau pressures <30 cm H_2O, and increasing Ti to minimize peak pressure resulted in low auto-PEEP. Regular bronchoscopes in 7.0-mm ETTs had similar results. Large bronchoscopes in 7.5-mm ETTs generated plateau pressures ranging from 28 to 35 cm H_2O with modest auto-PEEP. *Severe ARDS lung model:* Slim bronchoscopes in 6.0-mm ETTs resulted in plateau pressures of 46 and an auto-PEEP of 5 cm H_2O. Regular bronchoscopes in 7.0-mm ETTs generated similar results. Large bronchoscopes in 8.0-mm ETTs displayed plateau pressures of 44 and an auto-PEEP of 2 cm H_2O.

Conclusion: To mitigate risk of laryngeal injury, larger ETTs during bronchoscopy should be avoided. Our data show bronchoscopy with any ETT causes auto-PEEP and high plateau pressures, especially in lungs with poor compliance; however, ETT less than 7.5 mm can be used when considering several factors. Our data also suggest similar studies in patients with varying degrees of ARDS would be informative.

Key Words: laryngeal injury, prolonged intubation, endotracheal tube size, acute respiratory distress syndrome, airway pressures

Level of Evidence: NA

Laryngoscope, 133:147-153, 2023

- Simulation model of normal and ARDS lungs
- Three sizes of bronchoscopes (Ambu aScope4) in ETT sizes 6.0 – 8.0
- Assess the increase of airway resistance and the occurrence of auto-PEEP during bronchoscopy
- Determine a minimum ETT size to limit airway injury while permitting safe bronchoscopy
- Increasing inspiratory times to decrease flow and peak pressure (Ppeak) leads to auto-PEEP accumulation with negative physiological consequences and barotrauma risk
- Performing bronchoscopy with any size ETT comes at a risk of accumulating auto-PEEP and increased plateau pressures

Bigger Isn't Always Better

- **'Normal' lungs:** Regular bronchoscopes (comparable to Ambu aScope4: 5.0 mm with 2.2 mm working channel) are usable in 7.0 ETTs
  - Increasing Ti to minimize Ppeak resulted in only low levels of auto-PEEP
- **'ARDS' lungs:** Regular bronchoscopes are usable in 7.0 mm ETTs and large bronchoscopes (comparable to Ambu aScope4: 5.8 mm with 2.8 mm working channel) **if** Ti is low
  - Increasing Ti resulted in higher levels of auto-PEEP in both instances
  - Extreme caution and attention to auto-PEEP levels is vital
  - Particularly in ARDS andS ARS-CoV-2 patients , selection of ETTs smaller than 7.5 mm should permit safe lower respiratory tract sampling **without** the need for a large bronchoscope

Reflexively intubating ARDS patients in respiratory failure with 8.0 mm ETTs for bronchoscopy should be avoided![8]

[8]Kelebeyev, S., Davison, W., Ford, B. L., Pitman, M. J., & Bulman, W. A. (2023). The Effects of Endotracheal Tube Size During Bronchoscopy in Simulated Models of Intubated Patients. The Laryngoscope, 133(1), 147–153. https://doi.org/10.1002/lary.30074

Disposable Bronchoscope Sizing Availability

Ambu aScope4 Regular
OD 5.0
IP 5.4
WC 2.2

Ambu aScope4 Large
OD 5.8
IP 6.3
WC 2.6

Ambu aScope5 HD Regular
OD 5.0
IP 5.7
WC 2.2

Ambu aScope5 HD Large
OD 5.6
IP 6.3
WC 2.65

Boston Scientific Exalt Model B Regular
OD 5.0
IP 5.5
WC 2.0

Boston Scientific Exalt Model B Large
OD 5.8
IP 6.3
WC 2.6

Karl Storz C-MAC FiveS 5.3
OD 5.3
IP 5.3
WC 2.2

TSC Endovision Broncoflex Vortex
OD 5.6
IP 5.6
WC 2.8

Olympus H-SteriScope Normal
OD 4.9
IP 4.8
WC 2.2

Olympus H-SteriScope Large
OD 5.8
IP 5.7
WC 2.8

Olympus H-SteriScope Extra
OD 5.0
IP 5.7
WC 2.2

Verathon Bflex 5.8
OD 5.8
IP 6.4
WC 3.0

Verathon Bflex 5.0
OD 5.0
IP 5.5
WC 2.0

OD=Outer Diameter in mm
IP=Insertion Point Measurement in mm
WC=Working Channel in mm

Key Things to Remember

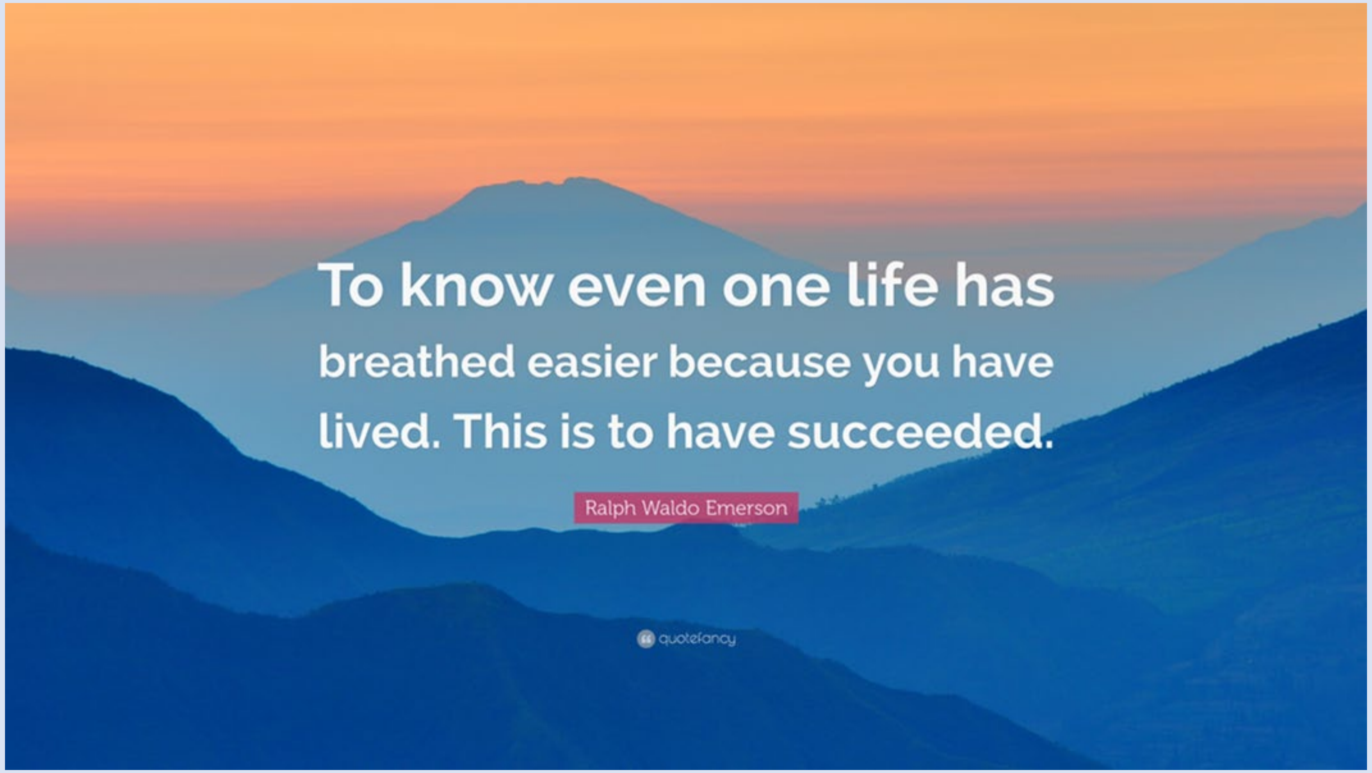
- ETT sizes refers to the internal diameter in mm
- Smaller size ETTs should be used for routine anesthesia; reduces concerns for its placement, especially in cases with difficult airways[5]
- An oversized ETT poses a significant risk for various well-known complications such as glottic and subglottic stenoses, vocal cord immobility, and arytenoid dislocation which eventually may need complex airway surgeries including temporary or permanent tracheostomy tube placement[6]
- Even with an 8.0 mm tube, a large bronchoscope occupies more than half of the effective tube diameter which can lead to increased airway pressures, increased auto-PEEP, reduced tidal volumes, hypoxia and hypercapnia[3]

[3] Farrow S, Farrow C, Soni N. Size matters: choosing the right tracheal tube. Anaesthesia. 2012 Aug;67(8):815-9. doi: 10.1111/j.1365-2044.2012.07250.x. PMID: 22775368

[5]Brodsky, M. B., Akst, L. M., Jedlanek, E., Pandian, V., Blackford, B., Price, C., Cole, G., Mendez-Tellez, P. A., Hillel, A. T., Best, S. R., & Levy, M. J. (2021). Laryngeal Injury and Upper Airway Symptoms After Endotracheal Intubation During Surgery: A Systematic Review and Meta-analysis. *Anesthesia and analgesia*, *132*(4), 1023–1032. https://doi.org/10.1213/ANE.0000000000000052

[6]Aljathlany, Y., Aljasser, A., Alhelali, A., Bukhari, M., Almohizea, M., Khan, A., & Alammar, A. (2021). Proposing an Endotracheal Tube Selection Tool Based on Multivariate Analysis of Airway Imaging. *Ear, nose, & throat journal*, *100*(5_suppl), 629S–635S. https://doi.org/10.1177/0145561319900390

THANK YOU!


To know even one life has breathed easier because you have lived. This is to have succeeded.
Ralph Waldo Emerson
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