

How to Prevent Endotracheal Tube Cuff Overinflation: “5 for 25”

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Adverse effects associated with elevated endotracheal (ET) tube cuff pressures above 25 cm H₂O include postoperative throat pain and tissue ischemia. Anesthesia practitioners' current methods of cuff pressure estimation are often inaccurate. This quantitative, quasi-experimental quality improvement project evaluated the incidence of ET tube cuff overinflation before and after an educational intervention that recommended the use of a 5-mL over 10-mL syringe for cuff inflation. Cuff pressures were measured at 2 hospitals within a large academic health system. The mean ET tube cuff pressure before education was 46.8 cm H₂O and after education was 27.1 cm H₂O (P=.001). The postintervention average cuff pressure using a 10-mL

syringe was 36.8 cm H₂O vs 21.1 cm H₂O when providers used a 5-mL syringe (P=.039). The relationship between syringe size and cuff pressure was significant (P=.001) with a positive Pearson correlation of 0.471. The ET tube cuff pressures were reduced by 42% after the intervention. Average cuff pressures when providers used a 5-mL syringe were 55% lower than with use of a 10-mL syringe. No critically high postintervention pressures were recorded when a 5-mL syringe was used. The authors recommend 5-mL syringes be used for inflation of an ET tube cuff.

Keywords: Endotracheal tube, cuff pressure, measurement, sore throat, tracheal ischemia.

More than 20 million endotracheal (ET) tubes are used annually in the United States.¹ Manual inflation of an ET tube cuff by an anesthesia provider may result in cuff pressures out of goal range, either underinflated or overinflated. Underinflation of an ET tube cuff can be identified by low tidal volumes and auditory air leaks indicating the cuff has not adequately sealed against the tracheal wall. Sultan et al² noted that the ET tube cuff should be inflated to the minimum volume at which no air leak is present with positive pressure inspiration and should remain less than 25 cm H₂O.

Overinflation of an ET tube cuff can cause elevated cuff pressures and may lead to adverse events.²⁻⁴ Overinflated cuffs are not as easily identifiable, explaining why there is a higher incidence of overinflation.^{1,2} Excessive cuff pressure may result in tracheal mucosal injury, vocal cord dysfunction resulting from recurrent laryngeal nerve palsy, and sore throat.² Cuff overinflation leads to laryngotracheal complaints such as sore throat caused by tissue ischemia.³ In fact, throat pain is the primary complaint by patients whose ET tube cuffs are overinflated.⁴

Cuff overinflation and sore throat can be avoided by inflating the correct amount of air into the cuff.¹ Using a manometer for ET tube cuff inflation yields real-time, accurate cuff pressure readings, but their use in the operat-

ing room (OR) is not always readily available. Anesthesia providers must then rely on 1 of 2 remaining inflation methods: the minimal occlusive leak test (MOLT) or palpation of the pilot balloon. Providers also may use the MOLT or the palpation method for measuring ET tube cuff pressure. The MOLT method involves inflating the ET tube cuff with air until there is an absence of an audible air leak while simultaneously ventilating the patient with adequate tidal volumes. Successful performance suggests that air no longer flows around the outside of the cuff but instead through the ET tube and into the patient's lungs as desired. Although the MOLT may be effective, it may not be performed regularly because of time constraints.

Palpation of the pilot balloon involves feeling the balloon between 2 fingers to determine if the balloon is firm enough. This indicates the sealing pressure within the ET tube cuff is high enough to deliver adequate tidal volumes. Although the palpation method may be considered efficient, this technique has demonstrated unreliability and often leads to cuff overinflation.² If a provider routinely inflates up to 10 mL of air into the pilot balloon, dangerously high cuff pressures (>25 cm H₂O) may result.⁴ This is because, on average, overinflated ET tube cuffs are filled with more than 5 mL of air.⁴ In theory, using a 10-mL syringe leads to cuff overinflation because less than 5 mL is actually needed. Currently,

there is no evidence that suggests using a 10-mL syringe reliably produces cuff pressures within goal range of 18 to 25 cm H₂O.

The purpose of this quality improvement project was to evaluate the incidence of ET tube cuff overinflation at 2 hospitals' ORs, and to determine whether an educational intervention advocating the use of a 5-mL syringe in place of a 10-mL syringe would reduce the incidence of cuff overinflation.

Literature Review

A review of the literature was conducted to gain insights into ET tube cuff pressures and educational interventions. The journal databases WorldCat.org, PubMed and MEDLINE, and Cumulative Index to Nursing & Allied Health Literature (CINAHL) were used for the review of the literature. The search terms *endotracheal tube, cuff, pressure, assessment, technique, tracheal ischemia, throat pain, sore throat, and measurement* were entered. Results were narrowed to only those available online, in English, and in full-text, peer-reviewed format between 2011 and 2018. The remaining articles were reviewed, selecting only those that contained information regarding cuff pressure measurements and comparison of inflation techniques.

• **Cuff Pressure Effect on Postoperative Throat Pain.** Ansari et al⁵ evaluated postextubation throat pain in patients undergoing maxillofacial surgery. Cuff pressures between an experimental and control group were measured, and methods of cuff inflation were compared. In the experimental group, cuff pressures were measured using a pressure gauge manometer at the beginning of surgery, then adjusted once every subsequent hour using the same pressure gauge manometer. In the control group, an experienced anesthesiologist adjusted the cuff pressure at the beginning of the operation via the traditional method (palpation of the pilot balloon or MOLT). Control group cuff pressures were also adjusted every hour but using traditional methods. Throat pain measurements at postoperative hours 1, 6, and 24 were 3.9, 3.1, and 1.6, respectively, in the experimental group compared with 5.3, 4.5, and 1.9 in the control group.⁵ This study demonstrates that even in experienced hands, traditional methods of cuff inflation result in higher throat pain scores postoperatively.

Cuff pressures can increase from baseline during laparoscopic procedures and with position changes such as Trendelenburg. Geng et al⁶ examined the effect of changes in ET tube cuff pressure on postoperative sore throat during gynecologic surgery performed laparoscopically vs laparotomy. Patients were intubated, and ET tube cuffs were inflated to a set pressure of 25 mm Hg (35 cm H₂O) using handheld manometers. Cuff pressures were then reassessed at intervals of 5, 15, 30, 45, and 60 minutes. In the laparoscopic group, ETT cuff

pressures rose as high as 34.2 ± 4.8 mm Hg (46 cmH₂O ± 6 cmH₂O) just 5 minutes post Trendelenburg position change and abdominal CO₂ insufflation.⁶ These pressures remained elevated for the duration of the case. Postextubation sore throat in the laparoscopic group at 2 hours postoperatively had a mean pain score of 2.5 at rest and 2.7 when swallowing.⁶ The laparotomy group had a mean pain score of 0.7 at rest and 1.3 when swallowing.⁶ This study found that position changes and laparoscopic abdominal insufflation caused elevated ET tube cuff pressures, resulting in a positive correlation with the incidence of postoperative sore throat.

Pediatric patients are at particularly high risk of cuff overinflation. Calder et al⁷ evaluated the incidence of and risk factors for postoperative sore throat in 500 intubated children aged 3 to 16 years undergoing elective same-day surgery. The ET tube cuff pressures were assessed using the MOLT method and then verified using handheld manometers. Overall, cuff pressures measured ranged from 0 to 92 cm H₂O with a median value of 16 cm H₂O, and 22% of children developed a sore throat.⁷ There were no complaints of sore throat in patients whose cuff pressure measured 0 to 10 cm H₂O.⁷ As cuff pressures increased, so did the incidence of sore throat. Sore throat was present in 4% of patients with cuff pressures between 11 and 20 cm H₂O, 20% of patients with cuff pressures between 21 and 30 cm H₂O, 68% of patients with cuff pressures between 31 and 40 cm H₂O, and 96% of patients with cuff pressures above 40 cm H₂O.⁷ Use of cuffed ET tubes in children is growing in popularity, demonstrating the incidence of sore throat with cuff overinflation in this population.

• **Inflation Method.** Al-Metwalli et al⁴ performed a prospective, controlled, randomized, double-blind experimental study in 75 patients comparing a controlled manometer group, pilot balloon palpation group, and a sealing group (MOLT method). The controlled manometer group had a mean cuff pressure of 25 cm H₂O and used 4.3 mL of air for cuff inflation.⁴ The sealing group had a mean pressure of 20 cm H₂O using 3.8 mL of air, and the pilot balloon palpation group had a mean pressure of 48 cm H₂O using 6.8 mL of air for inflation.⁴ The pilot balloon palpation group was the least reliable method for verification of ET tube cuff pressures, leading to overinflation of pilot balloons. It is noteworthy that for the groups that had cuff pressures within range (<25 cm H₂O), less than 5 mL of air was used.⁴ This supports the theory that using a 5-mL syringe could reduce the incidence of ET tube cuff overinflation.

Michlig⁸ asked 53 different anesthesia providers in the United Kingdom to estimate the cuff pressure using the palpation method in a cuff that had been grossly overinflated to 120 cm H₂O. This value is 4 times the recommended maximum limit of 30 cm H₂O. Eighteen participants estimated the pressure to be too high, 17

estimated the pressure to be too low, and 18 estimated the pressure was correct/appropriate.⁸ With only about one-third of participants correctly estimating the cuff pressure, this study clearly demonstrates that even when a cuff is grossly overinflated, the palpation method is highly ineffective. A prospective, observational study performed by Khan et al⁹ found similar inaccuracies in the palpation method. In 100 patients with ET tube cuffs inflated using conventional practices for inflation, none were within the goal range of 20 to 30 cm H₂O and 69% were above the recommended range.⁹

The intubated intensive care unit (ICU) population offers additional insight into overinflated cuff sequelae because these patients are often intubated for longer periods than those undergoing surgery. The hospital-associated variable most associated with tracheal stenosis was ET tube cuff pressures greater than 30 mm H₂O for longer than 10 days.¹⁰ An audit of 45 ICU patients in Parkville, Australia, found that the use of the MOLT method resulted in 14 of 45 patients with measured ET tube cuff pressures of 41 cm H₂O or higher.¹¹ This is of particular concern given that ICU patients are often intubated for long periods, leading to potential long-term damage from tracheal tissue ischemia. Totonichi et al¹² also looked at ICU patient cuff pressures. They performed a cross-sectional study in 101 patients aged older than 18 years who underwent open heart surgery and were placed in a postsurgical ICU under mechanical ventilation. On admission to the ICU, registered nurses performed both MOLT and palpation methods of cuff inflation for the same patient. After each method of inflation was performed, exact pressures were obtained using a manometer. In the pilot balloon palpation group, the average ET tube cuff pressure was 54.09 cm H₂O and the range measured 12 to 100 cm H₂O.¹² In the minimal occlusive volume group, the average ET tube cuff pressure was 43.9 cm H₂O and the range was 22 to 100 cm H₂O.¹² Although both methods led to cuff overinflation, pilot balloon palpation generated significantly higher cuff pressures.

• **Provider Experience and Education.** To determine if provider type affects the accuracy of ET tube cuff measurement, Hedberg et al¹³ compared nurse anesthetists and anesthesiologists using the pilot balloon palpation method on artificial tracheas with an ET tube cuff set at 95 cm H₂O. They found that neither work experience nor provider type had a statistically significant impact on appropriate cuff inflation.¹³ Overall, 89.1% of providers estimated the cuff pressure to be high, and 10.9% thought the pressure was adequate to low.¹³ An ET tube cuff pressure at this level is high enough to completely occlude tracheal blood flow, leading to tissue necrosis, yet 10% of these providers failed to recognize the critically high cuff pressure.¹³ Saracoglu et al¹⁴ also determined that there was no difference in professional experience when

determining accurate ET tube cuff pressures. A total of 34 anesthesia technicians, 16 anesthesia residents, and 12 anesthesiologists were asked to inflate the cuff balloon to the level they felt was appropriate, with many performing an air leak test (similar to MOLT). Cuff pressures were then measured using an aneroid cuff manometer, but values were not disclosed. The results showed no significant difference in the average cuff pressure between providers with different levels of professional experience, and all cuff pressures measured were above goal range.¹⁴

• **Value of Education.** The first step in making a practice change is providing education. Siamdoust and colleagues¹⁵ provided a 2-week educational in-service for 52 anesthesia providers on appropriate ET tube cuff inflation. Before the educational in-service, only 24.2% of cuff pressures were within the recommended range, with the average pressure reading 51 cm H₂O.¹⁵ After the educational in-service, 39.7% of cuff pressures were within the normal range, with an average cuff pressure of 45 cm H₂O.¹⁵ The cuff pressures improved significantly after the intervention, suggesting that educational programs are beneficial for cuff inflation practices.

Ashman and coworkers¹⁶ improved compliance of cuff pressure monitoring by instituting a multistep intervention consisting of departmental education, OR reference cards, and electronic record documentation. To begin, baseline cuff pressures were measured and results were shared with the anesthesia providers. The initial average cuff pressure was 34 cm H₂O.¹⁶ Next, 4 studies were presented to the anesthesia staff that showed a decrease in postoperative pharyngeal complications when cuff pressures were controlled; 3 of the studies showed the inaccuracy of pilot balloon palpation. A sign was placed in each OR that listed the recommended cuff pressures for that institute. Last, incorporation of reminders and cuff pressure documentation was added to the electronic record. Postintervention average cuff pressures dropped to an average of 29 cm H₂O.¹⁶ This multistep approach to increasing cuff pressure awareness and reduction of cuff pressures was highly effective and was used as a guide by the researchers of this project.

Methods

This quality improvement project took place in 25 ORs at NorthShore University HealthSystem's Evanston Hospital (17 ORs) in Evanston, Illinois, and Glenbrook Hospital (8 ORs) in Glenview, Illinois. The target population for all phases of the project consisted of approximately 110 anesthesia providers including anesthesiologists, Certified Registered Nurse Anesthetists (CRNAs), student registered nurse anesthetists, and anesthesia residents. In compliance with exempt-status IRB requirements for maintaining confidentiality, no provider information was recorded, including level of educational experience. Inclusion criteria were cases performed using

general anesthesia with an ET tube. Case exclusion criteria included the use of nitrous oxide, the use of specialty ET tubes (eg, laser or neural integrity monitor tubes), and the use of supraglottic airway devices. Data were also excluded if any anesthesia provider refused participation.

This quantitative, quasi-experimental project evaluated ET tube cuff pressures and syringe size used for cuff inflation before and after an educational intervention. The study was performed in 3 phases: (1) a preintervention data collection phase, (2) an educational intervention, and (3) a postintervention data collection phase. This study was reviewed and approved by the institutional review boards (IRBs) of NorthShore University HealthSystem and DePaul University, Chicago, Illinois. All researchers involved underwent training in research, ethics, and compliance (Collaborative Institutional Training Initiative [CITI Program]).

• **Phase 1: Preeducational Intervention Data Collection.**

On day 1 of data collection, the researchers arrived unannounced to the study sites. Data collected included body mass index (BMI), patient position, ET tube size, size of the syringe used for cuff inflation, and ET tube cuff pressure (in cm H₂O). A digital manometer (manufactured and provided by Hospitech Respiration Ltd) was used for data collection at each hospital setting. The same anesthesia providers were involved in several samples taken throughout the day, but ET tube cuff pressures were measured only once per case. The timing of ET tube cuff measurements was variable.

The researchers arrived unannounced to prevent anesthesia providers from adjusting their cuff inflation practices and to provide the most accurate baseline data. If providers inquired about the measurements that were being collected, they were informed about the data collection process, but the exact cuff pressure reading was not disclosed. An exception was made if cuff pressures exceeded 60 cm H₂O. Per IRB requirements and to avoid harm to the patient, cuff pressures that were found to be greater than 60 cm H₂O were disclosed to the anesthesia provider immediately. This allowed the provider the opportunity to reduce the cuff pressure by removing air from the cuff and avoiding harm to the patient. No additional measurements were taken from these rooms for the remainder of the day because the anesthesia provider had been made aware of his or her high cuff inflation practice and all future cuff pressure readings could be biased.

• **Phase 2: Educational Intervention.** An educational flyer was created after a thorough review of the current literature (Figure 1). The educational flyer was designed to make anesthesia providers aware of the current, evidence-based methods to best verify appropriate ET tube cuff pressures and to make the providers aware of their own practices, in aggregate. The flyer was conceptually divided into 3 sections. The first section included the range of ET tube cuff pressures and the average ET

METHODS OF ETT CUFF INFLATION

NORTHSHORE STUDY FINDINGS
Randomized standard ETT cuff pressures were measured in all operating rooms at NorthShore Evanston and Glenbrook Hospitals

	Evanston Hospital	Glenbrook Hospital
Lowest Pressure Recorded (cm H ₂ O)	16	35
Highest Pressure Recorded (cm H ₂ O)	>99	>99
Average Pressure Recorded (cm H ₂ O)	42	55

Did you know....

- An endotracheal tube (ETT) cuff should be inflated to a pressure **no greater than 25 cm H₂O?**
- Excessive cuff pressure can cause tracheal mucosal injury, vocal cord dysfunction, and/or a sore throat.
- ETT cuffs need just enough volume to prevent air leaks during positive pressure ventilation.

How do you determine ETT cuff pressure?

Measure with a manometer Perform a minimally occlusive leak test Palpate pilot balloon

In a randomized control trial, Al-Metwalli et al. (2011) results showed:

Inflation Method	ETT Cuff Pressure Achieved	Inflation Volume Used
Manometer (control) group	25 cm H ₂ O	4.3 ml
Sealing group (minimal occlusive leak test)	20 cm H ₂ O	3.8 ml
Pilot balloon palpation group	48 cm H ₂ O	6.8 ml

PRACTICE PEARLS

The gold standard for measuring ETT cuff pressures is with the use of a monometer. Without a monometer, the next safest way to reduce cuff over-inflation is by:

- Performance of the minimally occlusive leak test
 - Deflate the cuff until a leak is audible, then re-inflate just until the leak is gone
 - For accuracy, use a stethoscope just below the larynx to auscultate the leak
- **Using a 5 ml syringe instead of a 10 ml syringe when inflating the ETT cuff**
 - Attaching a 5 ml syringe to the pilot balloon prior to intubation, serving as a reminder to use less air and thereby keeping cuff pressures below 25 cm H₂O

Remember 5 for 25!

Al-Metwalli, R., Al-Ghamdi, A., Mowafi, H., Sadek, S., Abdulkhafi, M., & Mousa, W. (2011). Is sealing cuff pressure, easy, reliable and safe technique for endotracheal tube cuff inflation?: A comparative study. *Saudi Journal of Anaesthesia*, 5(2), 185-189. doi:10.4103/1658-354X.82795

Hagberg, C.A. & Artime, C.A. (2015). Chapter 55: Airway Management in the Adult. In Miller's Anesthesia (8th ed.). Philadelphia, PA: Elsevier Saunders.

Figure 1. Educational Flyer
Abbreviation: ETT, endotracheal tube.

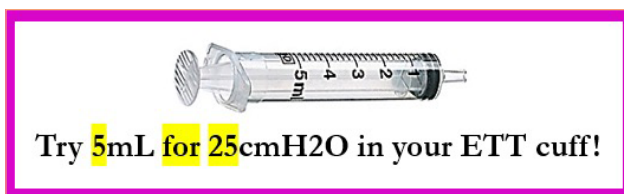


Figure 2. Proposed New Standard of Practice: “5 for 25”
Abbreviation: ETT, endotracheal tube.

tube cuff pressures of phase 1 from each hospital. The second section included facts on appropriate ET tube cuff pressures, consequences of cuff overinflation, and the main results of the 2011 study by Al-Metwalli et al.⁴ The third section listed “practice pearls,” which were evidence-based practice recommendations that describe ways in which an anesthesia provider can reduce the incidence of cuff overinflation. The researchers developed and included the mnemonic “5 for 25” to help the anesthesia providers remember the most important clinical pearl (Figure 2). The flyer was initially taped to the wall above the anesthesia cart, but because of unforeseen restrictions by the Joint Commission, the flyer had to be removed from the wall and was then placed into the ET tube drawer of the anesthesia cart.

• **Phase 3: Posteducational Intervention Data Collection.** One week after the educational flyer was posted, ET tube cuff pressures were again measured and recorded in the

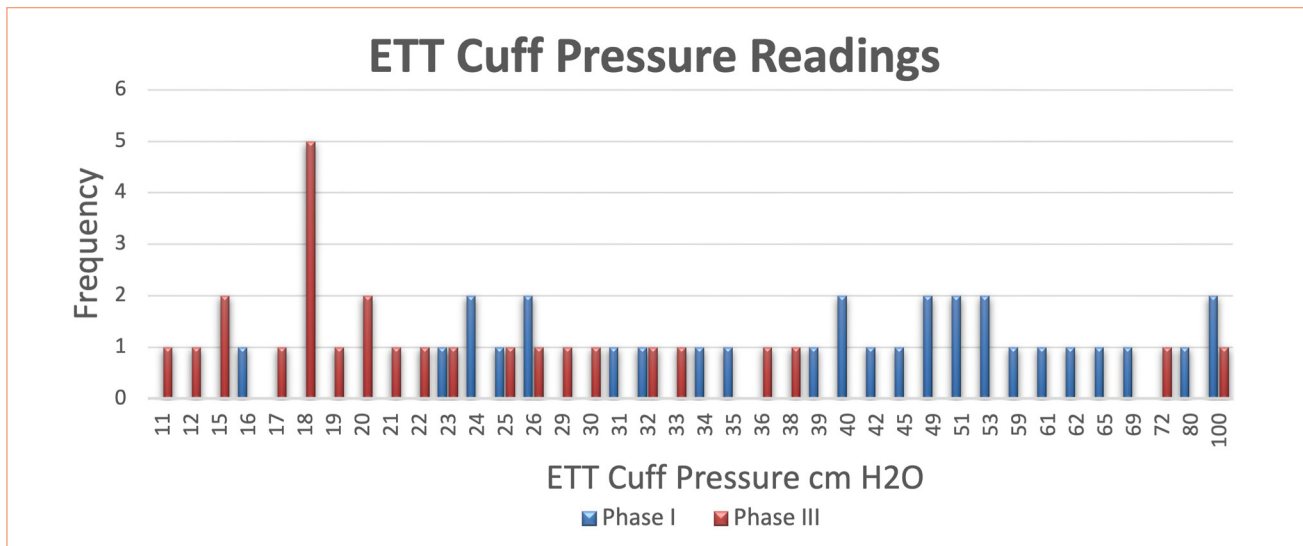


Figure 3. Endotracheal Tube Cuff Pressures Comparing Phase 1 With Phase 3
Abbreviation: ETT, endotracheal tube.

same manner as described in phase 1 and on the same group of providers. Inclusion and exclusion criteria remained the same as in phase 1.

Results

In total, 56 cuff pressures were measured in phases 1 (n=30) and 3 (n=26). Each measurement was performed on a different patient (assuming no patient came in for a second surgery on the same day).

- Phase 1 (Preeducational Intervention).** A total of 30 cuff pressures were measured in phase 1. The mean BMI (SD) was 30.9 (8.9) kg/m². The BMI ranged from 20 to 56 kg/m², with a mode of 26 kg/m² (n=4) and a normal distribution curve. The most common patient position observed was supine (n=17). Other positions recorded included Trendelenburg (n=2), lithotomy (n=5), prone (n=2), reverse Trendelenburg (n=2), and lateral (n=2). The ET tube sizes included 7.0 mm (n=12), 7.5 mm (n=13), 8.0 mm (n=4), and 8.5 mm (n=1), producing a normal distribution curve. In all 30 cases, 10-mL syringes were used to inflate the ET tube cuff. The mean ET tube cuff pressure was 46.8 (21.3) cm H₂O, ranging from 16 to 100 cm H₂O and producing a normal distribution curve. The frequencies of ET tube cuff pressures in phases 1 and 3 can be found in Figure 3.

- Phase 3 (Posteducational Intervention).** A total of 26 cuff pressures were measured in phase 3. The mean BMI was 27.4 (SD = 6.1), ranging from 17 - 46 with a mode of 24, 26, and 27 (n=3). Again, the most frequently recorded patient position was supine (n=15). Other patient positions included lithotomy (n=5), prone (n=4), reverse Trendelenburg (n=1), and sitting (n=1). The ET tube sizes used were either 7.0 mm (n=16) or 7.5 mm (n=10). There were 2 sizes of inflation syringes used: 10 mL (n=10) and 5 mL (n=16).

The mean ET tube cuff pressure (SD) during phase 3 was 27.1 (19.1) cm H₂O, ranging from 11 to 100 cm H₂O (Figure 3). The most frequently recorded ET tube cuff pressure was 18 cm H₂O (n=5). The mean ET tube cuff pressure using a 10-mL syringe was 36.8 (28.2) cm H₂O, and the mean ET tube cuff pressure using a 5-mL syringe was 21.1 (5.7) cm H₂O. The highest recorded ET tube cuff pressure using a 5-mL inflation syringe was 33 cm H₂O, whereas the highest recorded pressure using a 10-mL syringe was 100 cm H₂O.

- Combined Results of Phases 1 and 3.** The mean patient BMI was not significantly different between study phases (P=.08). The range of BMI measurements in phases 1 and 3 combined was 17 to 56 kg/m². However, a Pearson correlation revealed that the relationship between patient BMI and ET tube cuff pressure had a significant positive correlation (r=0.27, P=.04).

The relationship between patient position and ET tube cuff pressure was not found to be significant (r=0.05, P=.68). Patient position did not have a normal frequency distribution because of the large number of supine positions recorded; therefore, the effect of patient position on ET tube cuff pressures may not have been accurately represented in this study. The relationship between the size of ET tube and cuff pressure was not significant (r=0.12, P=.34).

An independent *t* test was done comparing ET tube cuff pressures between phase 1 and phase 3, proving the reduction in cuff pressure between the 2 phases was significant (P=.01). An independent *t* test including all 56 cases was calculated to compare the size of the inflation syringe with ET tube cuff pressure, proving significance in the reduction of cuff pressures using a 5-mL syringe (P<.01). A positive Pearson correlation of 0.471 was also found between the size of syringe and reduction in ET

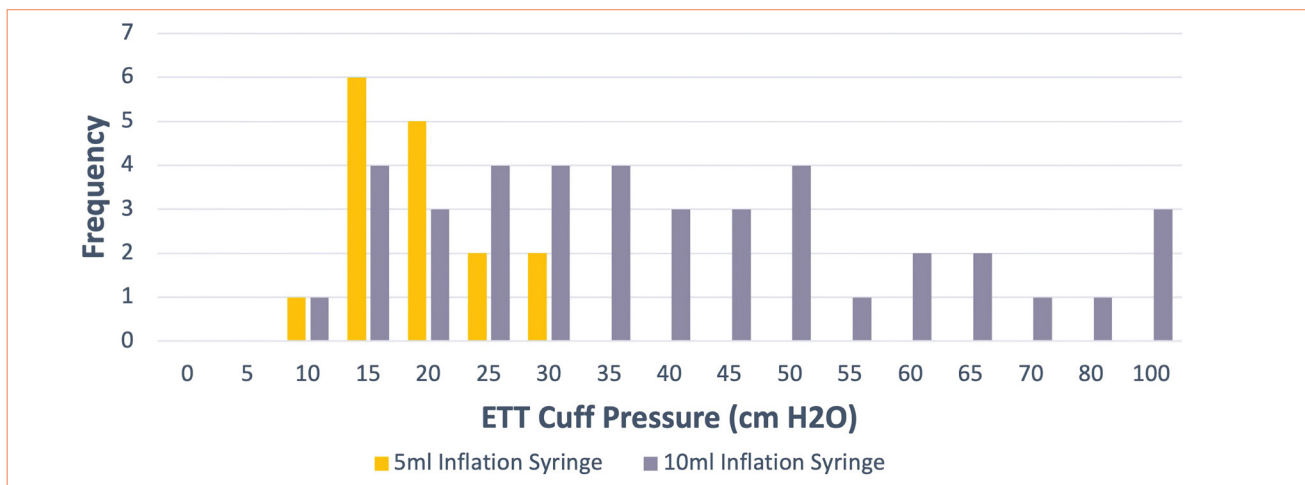


Figure 4. Proposed New Standard of Practice: “5 for 25”

Abbreviation: ETT, endotracheal tube.

tube cuff pressure. Figure 4 displays the distribution of ET tube cuff pressures in relation to the size of the inflation syringe used in phases 1 and 3 combined. The ET tube cuffs in phases 1 and 3 inflated with 10-mL syringes (n=40) resulted in pressures averaging 23.2 cm H₂O higher than those in phases 1 and 3 inflated with 5-mL syringes (n=16).

To determine the presence of a significant reduction in cuff pressures without the educational flyer being a variable, the researchers conducted a second independent *t* test with just phase 3 results comparing ET tube cuff pressure with the size of the inflation syringe, demonstrating a significant reduction in cuff pressure using a 5-mL syringe ($P=.039$).

Discussion

There was a comparable mean patient BMI in phase 1 (before the educational intervention) and phase 3 (after the educational intervention; $P=.08$). Results indicated that as the BMI increased, the ET tube cuff pressure also increased. Due to a lack of statistical significance in the difference of BMI between phase 1 and phase 3, it can be assumed that the BMI did not affect the cuff pressure between the phases. This finding suggested that any reduction in cuff pressure was due to the educational intervention or syringe instead of a possible reduction in BMI. Patient position and ET tube size did not have a significant effect on ET tube cuff pressure.

The mean ET tube cuff pressure decreased from 46.8 cm H₂O in phase 1 to 27.1 cm H₂O in phase 3. This represents a significant 42% reduction in average ET tube cuff pressure ($P<.001$), as all syringe sizes were included in the *t* test comparing cuff pressures before and after the intervention. The educational flyer may have even prompted providers who used 10-mL syringes to be cognizant of the overall volume of air inflated.

Endotracheal tube cuff pressures for phase 1 included

only 10-mL inflation syringes. The ET tube cuff pressures for phase 3 included both 5-mL and 10-mL inflation syringe sizes, revealing that some anesthesia providers chose to adjust their practice by selecting a 5-mL syringe based on the educational intervention. The independent *t* test was performed a second time using only phase 3 results to account for the possible changes in cuff pressures after the educational intervention. In this analysis of syringe sizes using only phase 3 data, the average cuff pressure when the provider used a 10-mL syringe was 36.8 cm H₂O, and the average cuff pressure with use of a 5-mL syringe was 21.1 cm H₂O ($P=.039$). The use of a 5-mL syringe resulted in a 55% reduction in ET tube cuff pressures from baseline (phase 1). Since both groups (5-mL syringe users and 10-mL syringe users) in phase 3 had access to the educational flyer, it can be assumed that the most important variable affecting the reduction in cuff pressure was syringe size.

In the first phase, 7 cuff pressures were measured critically high (>60 cm H₂O), requiring the researchers to divulge the cuff pressure readings to the provider. Following the educational intervention (phase 3), only 2 pressures measured critically high, and both were with the use of a 10-mL syringe for cuff inflation. No 5-mL syringes yielded a cuff pressure above 60 cm H₂O during phase 3. The use of a particular syringe size does not guarantee that those exact amounts of air were inflated into the ET tube cuffs themselves. Several practitioners stated that they used a 10-mL syringe but inflated only 5 mL of air. The results of this study demonstrate that even if more than 5 mL of air is needed to reach a sealing cuff pressure, the use of a 10-mL syringe is more likely to cause cuff overinflation. Every cuff pressure reading of 100 cm H₂O in this study (both phases 1 and 3) was achieved with a 10-mL syringe.

Overall, the data suggested that even if a 10-mL syringe is used and the practitioner chooses to inflate

less than 10 mL of air, the cuff is still more likely to be overinflated. Given that the average cuff pressure using a 5-mL syringe was 55% lower than with a 10-mL syringe and no critically high pressures were recorded using a 5-mL syringe, the authors recommend that providers change their practice to use a 5-mL syringe when inflating ET tube cuffs. This represents a practice shift, but the findings from this project support that overinflation can be reduced with the use of a 5-mL syringe.

This study has some limitations. To comply with IRB requirements in an exempt study, the recruitment email had to be distributed before collection of any data. To minimize the impact of the Hawthorne effect, in which study participants may alter their behavior when they are aware their behavior is being observed,¹⁷ the recruitment email notifying anesthesia providers that cuff pressures would be measured was distributed as far in advance as possible and providers were not made aware of the data collection dates. The recruitment email was sent 3 months before the initial date of data collection.

In compliance with IRB requirements for de-identified data, the researchers could not record the OR or the anesthesia provider identity. It is possible that the providers adjusted their practice throughout the data collection period by reducing the amount of air used to inflate the ET tube cuff for each subsequent case, thereby lowering the cuff pressure, reducing the overall cuff pressure average, and altering the frequency of distribution. Ultimately, providers' awareness likely had little impact on their practice because the average cuff pressure for phase 1 was well above goal range.

The digital manometer used to measure cuff pressures registered any pressure above 99 cm H₂O as "OP," which stands for "over pressure," and the exact cuff pressure could not be determined. When the researchers entered this information for analysis, they used a pressure of 100 cm H₂O for all pressures reading OP. Phase 1 had 2 recorded cuff pressures above 99 cm H₂O, and phase 3 had one cuff pressure recorded above 99 cm H₂O. As a result, the mean cuff pressures may have been underestimated, more so in phase 1 than phase 3. Because of this, the difference in average cuff pressure from phase 1 to phase 3 may have actually been higher than the calculated 42% reduction. Timing of ET tube cuff measurements during a surgery was not controlled for in this study.

Conclusion

This project demonstrated that an educational flyer reduced overall ET tube cuff pressures by 42%. The most significant factor in maintaining cuff pressures within goal range was the use of a 5-mL syringe, which resulted in a 55% reduction in cuff pressures. No critically high ET tube cuff pressures were measured when a 5-mL syringe was used. With the strong correlation found between inflation syringe size and ET tube cuff

pressure, the authors recommend that all providers use a 5-mL syringe when inflating an ET tube cuff. Although 5 mL of air may not be the exact volume of air required for inflation of ET tube cuffs for all patients, it serves to limit the amount of air initially inflated and acts as a reminder for the anesthesia provider to be cognizant of the cuff pressure. Future studies need to be completed to assess the total volume of air required to yield ET tube cuff pressures within goal range. In addition, further studies should be done to assess the effect of patient position on ET tube cuff pressure.

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