© 2024 EDIZIONI MINERVA MEDICA
Online version at https://www.minervamedica.it

Minerva Anestesiologica 2024 mese;90(0):000–000
DOI: 10.23736/S0375-9393.24.18078-9

ORIGINAL ARTICLE

A comparative analysis of elevated endotracheal tube cuff pressure incidence in laparoscopic abdominal surgery: saline *versus* air inflation

Ozge SIKTAS, Ersel GULEC *, Mediha TURKTAN, Zehra HATIPOGLU, Demet LAFLI TUNAY, Dilek OZCENGIZ

Department of Anesthesiology and Reanimation, Cukurova University Faculty of Medicine, Adana, Türkiye

*Corresponding author: Ersel Güleç, Department of Anesthesiology and Reanimation, Çukurova University Faculty of Medicine, 01380, Adana, Türkiye. E-mail: gulecersel@yahoo.com

ABSTRACT

BACKGROUND: Endotracheal intubation is a frequently performed procedure in anesthesia practice, and ensuring the correct inflation of the cuff is essential for maintaining the airway seal. Overinflation of endotracheal tube (ETT) cuffs can lead to complications, such as postoperative sore throat. This study aimed to compare the incidence of elevated ETT cuff pressure between saline and air inflation in elective laparoscopic abdominal surgery.

METHODS: The study involved 60 participants ranging in age from 18 to 65, with American Society of Anesthesiologists physical status levels 1-2, who were undergoing laparoscopic abdominal surgery. We randomly assigned patients to two groups: Group A (air-filled ETT cuffs, N.=30) and Group S (saline-filled ETT cuffs, N.=30). Intra-cuff pressure was recorded before and after CO_2 insufflation, as well as during changes in patient position. The number of interventions to restore intra-cuff pressure to 18 mmHg was documented. Peak airway pressure, plateau pressure, and positive end-expiratory pressure (PEEP) were measured at 15-minute intervals.

RESULTS: The number of interventions needed to maintain intra-cuff pressure was significantly lower in the saline group compared to the air group. All patients started with initial cuff pressures above 20 mmHg. After insufflation, the first-minute cuff pressures were higher in the air group (P=0.001). Both groups experienced a significant increase in intra-cuff pressure with the Trendelenburg position, and after moving to the reverse Trendelenburg position (saline and air groups, P=0.001 and 0.012, respectively), the air group had higher intra-cuff pressure than the saline group (P=0.002). There were no significant differences between groups in peak airway pressure, plateau pressure, and PEEP.

CONCLUSIONS: Inflating ETT cuffs with saline instead of air during laparoscopic abdominal surgeries led to a reduced requirement for interventions in maintaining pressure. This indicates that the use of saline inflation may significantly lower the risk of high cuff pressure and related complications.

(*Cite this article as:* Siktas O, Gulec E, Turktan M, Hatipoglu Z, Lafli Tunay D, Ozcengiz D. A comparative analysis of elevated endotracheal tube cuff pressure incidence in laparoscopic abdominal surgery: saline *versus* air inflation. Minerva Anestesiol 2024;90:000–000. DOI: 10.23736/S0375-9393.24.18078-9)

KEY WORDS: Endotracheal anesthesia; Intubation; Laparoscopy; Saline solution.

Endotracheal intubation (ETI) is a frequently performed intervention involving the insertion of a tube into the trachea to secure an airway during surgeries. A cuffed endotracheal tube (ETT) is important to maintain effective ventilation by ensuring a proper seal. Maintaining cuff pressure within the optimal range of 20-30 cmH_2O is crucial for reducing potential risks associated with overinflation.[1-3] Overinflated high-volume and low-pressure cuffs can lead to increased strain on the tracheal mucosa, which may result in postoperative sore throat and other complications related to mucosal damage.[2, 4-6] Studies have shown the impact of nitrous oxide

(N_2O) diffusion into air-inflated cuffs, causing alterations in cuff volume and pressure for both high and low-volume cuffs.[7-10]

A combination of N_2O and air for inflating the ETT cuff has shown promise in reducing excessive cuff pressures and minimizing tracheal damage.[8] Other methods, including filling the tracheal cuff with saline, lidocaine, or distilled water, have also been suggested to manage fluctuations in intra-cuff pressure caused by N_2O.

These approaches have the potential to lower elevated pressures within the endotracheal tube cuff, thereby decreasing tracheal mucosal damage and improving postoperative airway-related symptoms.[4, 5, 11, 12] The insufflation of intra-abdominal CO_2 and changes in patient positioning can result in higher ETT cuff pressure, requiring prompt and efficient interventions.[13-18] There is a lack of comparative research on the effect of using air or saline to expand the ETT cuff during laparoscopic abdominal surgery on intracuff pressure.

The study was designed to show the impact of saline-filled cuffs as a possible substitute for conventional air-filled cuffs in regulating intra-cuff pressure during laparoscopic abdominal surgery. It was hypothesized that the use of saline-filled cuffs would result in a reduction in the need for interventions to minimize elevated intra-cuff pressures.

Materials and methods

This prospective, randomized, and controlled study was conducted at Cukurova University's Faculty of Medicine between September 2023 and November 2023, after approval by the Clinical Research Ethics Committee of Cukurova University (Approval Date: July 13, 2023; Decision No. 186/10). The research was recorded on ClinicalTrials.gov with the identification number NCT06089187 (Date of registration: September 26, 2023). The research protocol was designed by international Good Clinical Practice guidelines and the Helsinki Declaration. The reporting of study findings follows the Consolidated Standards of Reporting Trials (CONSORT). The patients, ranging in age from 18 to 65 years, were categorized as having a physical status of 1-2 according to the American Society of Anesthesiologists. They were scheduled to undergo elective laparoscopic abdominal surgery, which was expected to last between 30 and 120 minutes. The study excluded patients with neuropsychiatric disease, muscular disease, severe respiratory and cardiovascular disease, alcohol or drug dependence, morbid obesity, difficult intubation risk or prior tracheostomy, history of bronchospasm, and laryngeal disease or previous surgery.

After an 8-hour fasting period, vascular access was established in the preoperative preparation room upon obtaining written informed consent from the patients. No premedication was administered as part of the preoperative protocol. Upon arrival in the operating room, anesthesia monitoring was started with the following standard procedures: electrocardiography, non-invasive blood pressure measurement, peripheral oxygen saturation monitoring. Induction of anesthesia was started with an intravenous (IV) infusion of propofol at a dose of 2 mg/kg. The train-of-four monitor was adjusted to measure muscle relaxation before administering rocuronium IV at a dosage of 0.6 mg/kg to induce neuromuscular blockade. Additionally, IV fentanyl was given at a dose of 1 mcg/kg during anesthesia induction. ETI was done by a skilled anesthetist using a Macintosh laryngoscope with appropriate tube sizes when the TOF was 0. A large-volume, low-pressure ETT with suitable internal diameters was used for ETI.

Patient selection was performed using a computer-generated randomization table to ensure a randomized approach. After endotracheal intubation, the adjustable pressure-limiting (APL) valve was adjusted to maintain a pressure of 20 cmH_2O, with particular attention to ensure no detectable air leakage during balloon ventilation. Group A received air-filled ETT cuffs, while group S received saline-filled ETT cuffs.

We used a pressure channel of an operating room monitor; a method used in previous studies for continuous monitoring of intra-cuff pressure.[16, 19-22] Intra-cuff pressure was continuously monitored by connecting a pressure transducer to the cuff balloon via a three-way stopcock (Figure 1). Saline solution was used to irrigate

PROOF MINERVA MEDICA

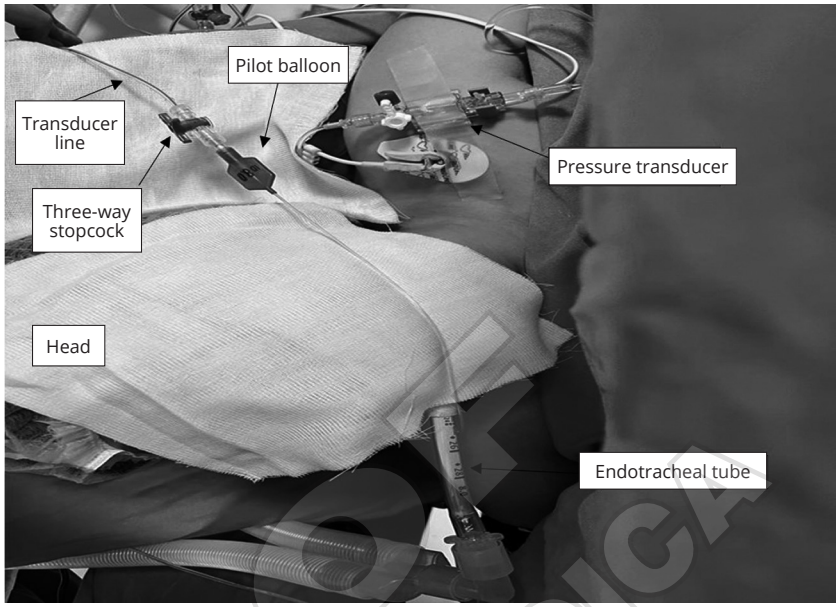


Figure 1.—Demonstration of the cuff pressure intervention and the pressure measurement equipment on the patient.

the transducer system to remove any air bubbles and all connections were properly secured to prevent disconnection or leakage. After calibration of the pressure monitor based on the sternal notch level, cuff pressure measurements were documented in mmHg units. After ETI, during volume-controlled ventilation, a tidal volume of 6-8 mL/kg was used, with positive end-expiratory pressure (PEEP) maintained at 5 cmH_2O. The respiratory rate was adjusted to maintain $EtCO_2$ levels within the range of 35-45 mmHg. To monitor the body's internal temperature, an esophageal probe was inserted. Anesthesia was maintained with sevoflurane and an oxygen/N_2O mixture (40%/60%) at a gas flow rate of 4 L/minute. As part of muscle relaxation maintenance, a dose of rocuronium at 0.15 mg/kg IV was administered upon reaching a train-of-four value of 2. Nasogastric tubes were inserted in all patients. For postoperative pain relief, IV tramadol was administered at a dose of 2 mg/kg along with paracetamol at a dose of 1 g around 30 minutes before the end of the surgery.

If the intracuff pressure remained above 20 mmHg for more than 30 seconds, a three-way stopcock and syringe were used to reduce the pressure to 18 mmHg. The number of interventions was recorded at 15-minute intervals, both before and after intra-abdominal CO_2 insufflation. The highest intra-cuff pressure was recorded during the first minute of CO_2 insufflation. Additional measurements included periodic recording of peak airway pressure, plateau pressure, and PEEP every 15 minutes throughout the intraoperative period. In addition, intracuff pressure was recorded before and after patients repositioning patients at a 30-degree angle in both reverse Trendelenburg and Trendelenburg positions. After the surgery, an IV administration of neostigmine at a dose of 0.04 mg/kg was given to reverse muscle relaxation, in addition to 0.015 mg/kg of atropine. After appropriate responses to verbal stimuli and a TOF of 90% or greater, the endotracheal tube was removed. After confirming adequate muscle strength and airway safety, patients were transferred from the operating room to the post-operative recovery area.

The primary study outcome was the number of interventions to restore intra-cuff pressure. Cumulative number of interventions was calculated separately before and after insufflation. The secondary outcomes included the maximum pressure during the first minute of CO_2 insufflation, intra-cuff pressure before and after Trendelenburg and reverse Trendelenburg positions, peak airway pressure, plateau pressure, and PEEP measurements.

EDITORIAL PROOF MINERVA MEDICA

Data availability statements

The data associated with the paper are not publicly available but are available from the corresponding author on reasonable request.

Statistical analysis

Based on our pilot study, we determined that each group would require a sample size of 27 patients, leading to a total of 54 patients (Table I). We enrolled 60 patients to mitigate potential data loss. The statistical analysis of the data was performed using SPSS 25.0 software. Categorical data was expressed using numbers and percentages, while continuous data was described using the mean and standard deviation (or median and interquartile range if not normally distributed). For categorical variables, we used either the chi-squared test or Fisher's exact test. To compare continuous measures between groups, we assessed the distributions. The variables with non-normal distribution were tested using the Mann-Whitney U test, while those with normal distribution were assessed using the Student's t-test. To compare results from repeated measurements among groups, a Repeated Measures Analysis of Variance (RM ANOVA) approach was employed. All statistical tests were conducted at a significance level of 0.05.

Results

Among the 65 patients who met the criteria for participation in the study, only 60 were able to fulfill the requirements of the study protocol. Of these participants, five underwent laparoscopic surgery and were subsequently converted to open surgery (Figure 2). Both groups had comparable demographic characteristics (Table II). There were no significant differences in initial cuff pressures between the groups. However, it was noted that all patients had initial cuff pressures significantly above 20 mmHg (27 cmH_2O).

No statistically significant differences were found between the groups in terms of BMI. Similarly, no significant statistical differences were found between BMI categories (<25; 25-29.9; >30) regarding the number of interventions before and after CO_2 insufflation. Post-insufflation measurements showed that the air group experienced a sharper increase in cuff pressures within the first minute, with pressures reaching a mean of 24.3±3.1 mmHg, compared to 20.9±2.4 mmHg in the saline group (P=0.001, Table III).

During the Trendelenburg position, the air group exhibited greater pressures of 23.9±4.7 mmHg, whereas the saline group had pressures of 21.9±2.5 mmHg. The RM ANOVA revealed a significant interaction between time and group (P=0.036), indicating that the change in cuff pressure over time differs considerably between the two inflation methods. We also found that there were significant differences over time within each group (P<0.001), as well as between the groups (P=0.002) (Table III).

Similarly, in the reverse Trendelenburg position, intra-cuff pressures changed significantly. The air group had a mean pressure of 23.5±3.1 mmHg following reverse Trendelenburg position, which was greater than the saline group's 19.1±2.9 mmHg (P=0.002). For the reverse Trendelenburg position, significant differences were noted over time (P=0.007), between groups (P=0.008), and an interaction effect (P=0.013), as detailed in Table III.

Throughout the surgical procedure, the saline

TABLE I.—*The table of power analysis elements.*

Power analysis	
We performed the POWER analysis:	*a priori*
on the primary outcome:	the number of interventions performed 30 min after CO_2 insufflation
based on the two-tailed statistical test:	parametric (two independent t) test
and accepting the cutoff for significance (α):	0.05
and a power (1–β) of:	0.95
The variability of the primary outcome was:	standard deviation (1.68)
based on data taken from:	the pilot study
We considered as clinically relevant a difference of:	-
Consequently, the effect size was:	1.012
The total sample size needed was:	54

PROOF MINERVA MEDICA

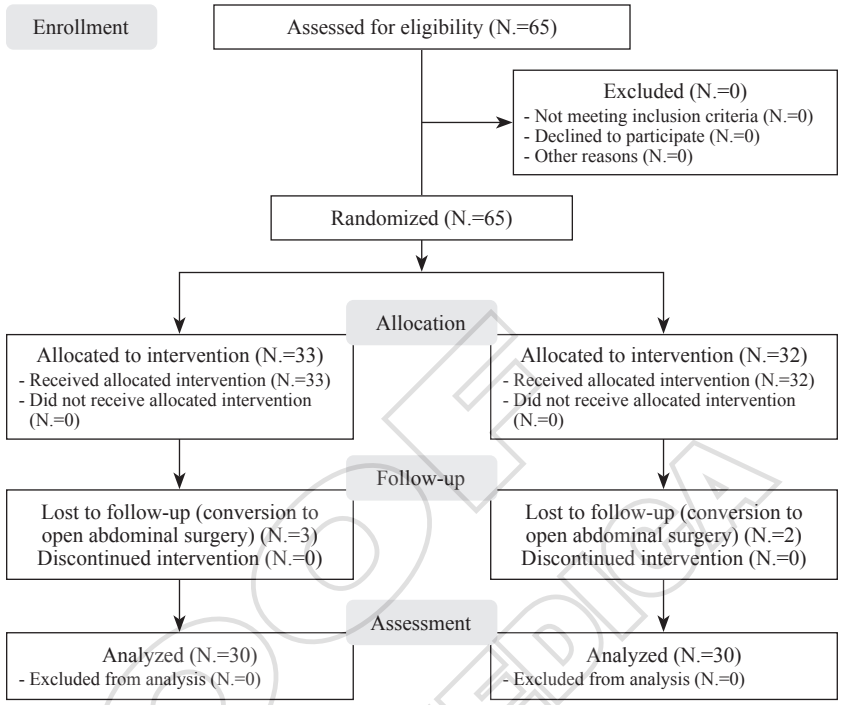


Figure 2.—CONSORT flow diagram of patient enrollment. CONSORT, Consolidated Standards of Reporting Trials.

TABLE II.—*Demographics and surgical data of the patients.*

Parameters	Group S (N.=30)	Group A (N.=30)	P value
Gender [a]			0.426
Female	17 (56.7%)	20 (66.7%)	
Male	13 (43.3%)	10 (33.3%)	
Age (years) [b]	46.2±11.9	46.2±11.2	0.991
BMI (kg/m^2) [b]	25.9±3.9	26.3±3.6	0.671
Surgery type [a]			1.000
Lap. inguinal hernia	15 (50.0%)	15 (50.0%)	
Lap. cholecystectomy	15 (50.0%)	15 (50.0%)	
Trendelenburg [a]			0.791
No	12 (40.0%)	12 (40.0%)	
Yes	18 (60.0%)	18 (60.0%)	
Reverse Trendelenburg [a]			0.791
No	18 (60.0%)	18 (60.0%)	
Yes	12 (40.0%)	12 (40.0%)	
Anesthesia duration (min) [b]	88.5±22.3	88.6±21.4	0.991
Laparoscopy duration (min) [c]	60 (45-75)	72.5 (45-75)	0.769
ETT diameter (mm) [a]			0.688
7.5	13 (43.3%)	10 (33.3%)	
8.0	1 (3.3%)	4 (13.3%)	
8.5	16 (53.3%)	16 (53.3%)	
Initial cuff pressure (mmHg) [b]	39.7±7.9	39.0±8.2	0.725

Values are mean±SD, median (IQR, interquartile range), or number (proportion).
[a] Chi-square test was used; [b] independent samples t-test was used; [c] Mann-Whitney U test was used; BMI: Body Mass Index; ETT: endotracheal tube.

group required fewer adjustments to maintain target cuff pressure (Table IV). No significant interaction effect was found between the time and group regarding the number of interventions (P=0.220). Furthermore, there was no significant difference over time within each group (P=0.501); nevertheless, a notable difference was observed between the two groups (P=0.033).

PROOF MINERVA MEDICA

TABLE III.—*Changes in intra-cuff pressure according to surgical positions in groups.*

Parameter	Group S (N.=30)	Group A (N.=30)	Independent-T test (P value)	RM ANOVA (P value)		
				Time	Group	Time x Group
Cuff pressure at 1 min after insufflation	20.9±2.4	24.3±3.1	0.001			
Pre-Trendelenburg	19.4±1.5	20.7±3.0	0.111	<0.001*	0.002	0.036
Post-Trendelenburg	21.9±2.5	23.9±4.7	0.130			
Pre-Reverse Trendelenburg	20.0±2.8	19.9±1.9	0.934	0.007**	0.008	0.013
Post-Reverse Trendelenburg	19.1±2.9	23.5±3.1	0.002			

Values are means±SD.
*Intracuff pressures were different between pre-Trendelenburg and 1 minute after insufflation, as well as between pre-and post-Trendelenburg; **intracuff pressures were different between pre-reverse Trendelenburg and 1 minute after insufflation. RM ANOVA, repeated-measures analysis of variance.

TABLE IV.—*The number of interventions to restore intra-cuff pressure at pre- and post-insufflation time intervals*

Timepoint	Number of interventions					Cumulative number of interventions				
	Group S		Group A		P value	Group S		Group A		P value
	N.	Mean±SD	N.	Mean±SD		N.	Mean±SD	N.	Mean±SD	
T0	29	1.1±0.9	30	2.0±1.0*	0.001	29	1.1±0.9	30	2.0±1.0*	0.001
T1	13	1.0±0.7	14	1.6±0.8*	0.042	13	2.2±1.3	14	3.9±1.5*	0.004
T2	30	1.4±0.9	30	2.0±1.0*	0.011	30	1.4±0.9	30	2.0±0.9*	0.011
T3	30	1.0±1.0	30	2.2±1.1*	0.001	30	2.4±1.7	30	4.2±1.7*	0.001
T4	29	1.5±0.9	29	2.1±1.1*	0.012	29	3.9±2.2	29	6.4±2.4*	0.001
T5	21	1.1±0.7	21	2.7±1.1*	0.001	21	4.9±2.7	21	9.0±2.6*	0.001
T6	11	1.2±0.9	16	2.3±0.9*	0.003	11	6.2±3.7	16	11.6±3.4*	0.001

Values are count and means± SD.
N: the number of patients intervened. Due to the variation in surgical times, the number of patients undergoing cuff pressure correction also varies. The number of interventions is the number of pressure corrective interventions performed at each time point (T) corresponding to the 15-min time interval. The cumulative number of interventions, encompassing the total interventions up to a specific point, was analyzed separately for both pre-insufflation and post-insufflation periods.
*P<0.05, compared to Group S, Independent-T test was used. T0: pre-insufflation 15 min; T1: pre-insufflation 30 min; T2: post-insufflation 15 min; T3: post-insufflation 30 min; T4: post-insufflation 45 min; T5: post-insufflation 60 min; T6: post-insufflation 75 min.

There was no significant difference in mean peak airway pressure, plateau pressure, or PEEP values. Additionally, no relationship was observed between these airway pressures and the number of interventions.

Discussion

The study investigated the use of air and saline inflation in cuff pressure control during laparoscopic abdominal surgery under general anesthesia with an N_2O gas mixture. We aimed to investigate a cuff inflation technique that reduces high cuff pressure through continuous pressure monitoring and we found that saline was more effective than air inflation.

Cuffed ETTs are essential for tracheal intubation, providing lung protection and proper ventilation. Inflating the cuff without leakage and maintaining pressure below 25 cmH_2O prevents complications. Regular monitoring of cuff pressure is recommended, particularly when using N_2O during anesthesia.[23, 24] Continuous monitoring of ETT cuff pressure can address challenges of multiple measurements during long-term surgeries and potential pressure reduction due to air leakage using a pilot balloon and manometer. An automated manometer offers a pragmatic solution to maintaining stable cuff pressure within a safe range throughout the procedure.[25, 26] In our study, we used continuous pressure measurement instead of automatic manometry to assess the impact of different cuff inflation techniques on the need for intervention to achieve optimal intracuff pressure.

Increased pressure in an endotracheal tube cuff can cause reduced mucosal perfusion, potentially causing damage and postoperative laryngotracheal complications.[2] ETT cuff pressure can be increased by the use of N_2O, patient positioning, and the intra-abdominal and intrathoracic pressures associated with laparoscopic surgery.[8-11, 13, 14] The Trendelenburg position

EDIZIONE MINERVA MEDICA

and CO_2 pneumoperitoneum can limit lung expansion, causing higher intra-cuff pressure and potential complications. Intra-cuff pressure is also increased by the head-down position used in laparoscopic procedures.[14-16, 18, 27-29] Our research indicates that the Trendelenburg position significantly increases cuff pressure, while the reverse Trendelenburg position only increases it when air is used to inflate the ETT cuff.

Extensive research on agents to prevent tracheal mucosal damage from excessive ETT cuff pressure during anesthesia has found that saline, as opposed to air, is more effective in preventing N_2O diffusion cuff pressure increases, emphasizing the importance of inflation mediums.[11, 30] Bennett *et al.* showed that air inflation increases cuff pressure, unlike saline inflation, which maintains stable pressures. However, this difference did not affect postoperative sore throat or hoarseness incidence.[4] Research is exploring the use of lidocaine as a preventative measure against post-operative sore throat and cough post-ETI, with a focus on determining the appropriate dosage and amount.[31, 32] Ahmad *et al.* showed that water-filled cuffs increase pressure slower than air-filled ones, suggesting the potential benefits of alternative inflation media for pressure stability.[12] Similarly, Mitchell *et al.* studied the effects of inflating tracheal tube cuffs with air, saline, or nitrous oxide/oxygen mixture in brain surgery patients. Air inflation increased cuff pressure without morbidity, while nitrous oxide/oxygen mixture cuffs caused leakage problems. Saline inflation required initial pressure stabilization.[33]

A study found that 89% of patients during laparoscopic pelvic surgery had ETT cuff pressures over 30 cmH2O upon palpation method, highlighting the issue of elevated pressures beyond the recommended threshold, potentially leading to complications.[16] Our research aimed to regulate cuff pressure to 20 cmH_2O by adjusting the pressure-limiting valve and inflating ETT cuffs. However, initial measurements often exceeded this target, highlighting the risks of excessively high cuff pressures during mechanical ventilation.

Sore throat after laparoscopic surgery has been associated with increased ETT cuff pressures during surgery. A study by Yildirim *et al.* found that post-operative sore throat in laparoscopic cholecystectomy patients was associated with an increased ETT cuff pressure, a significant increase compared to open surgery, and a higher incidence of sore throat in the laparoscopic group.[13] Geng *et al.*'s study compared laparoscopic and open gynecologic surgeries, revealing that patients undergoing laparoscopic procedures had higher cuff pressures, leading to increased postoperative sore throat complaints. Patients reported higher sore throat scores at 2 and 24 hours post-surgery, indicating potential discomfort following laparoscopic procedures.[17] A potential limitation of our study is that we did not assess complications related to cuff pressure, such as postoperative throat discomfort, as we focused on interventions to correct endotracheal tube cuff pressure.

Limitations of the study

The research has limitations, not extensively examining concerns regarding cuff pressure and post-surgery throat discomfort. Evaluating a broader range of complications could offer a more comprehensive understanding of managing cuff pressure's clinical significance. The study stresses the importance of tailored cuff management approaches for different surgical scenarios and emphasizes the need for further research on clinical implications and complications associated with long-term surgeries and various types of endotracheal tubes with different cuff designs.

Conclusions

In summary, saline-filled ETT cuffs are less likely to cause pressure increases compared to air-filled cuffs during elective laparoscopic abdominal surgeries. Continuous monitoring of cuff pressure is essential, particularly during laparoscopic procedures and patient repositioning, to prevent complications from overinflation. Notably, cuff pressure rises significantly in the Trendelenburg and reverse Trendelenburg positions when using air, highlighting the need for tailored cuff management strategies in various surgical situations. The use of automatic manometer devices that can maintain stable pressure when air is used to inflate the ETT cuff will prevent cuff pressure increases due to over-inflation, patient positioning,

EARLY ONLINE UNDER PEER REVIEW

or N_2O diffusion. Above in the setting of laparoscopic surgery, our findings suggest to use an air-oxygen mixture to ventilate the patients. Additional research should explore the direct clinical consequences and potential complications associated with various methods of cuff inflation during laparoscopic surgery.

What is known

• Endotracheal tube (ETT) cuff overinflation requires careful monitoring and adjustment of cuff pressure during surgery as it can lead to complications such as post-operative sore throat.

• Cuff pressure dynamics are determined by factors such as the insufflation agent used, patient positioning and the intraoperative use of gases such as nitrous oxide, which can diffuse into air-filled cuffs and change pressure levels.

What is new

• This study demonstrates that using saline to inflate ETT cuffs during laparoscopic abdominal surgeries significantly reduces the need for interventions to adjust cuff pressure compared to air, indicating better stability of intra-cuff pressure.

• Inflating ETT cuffs with saline may reduce the risk of high cuff pressures and associated complications, suggesting that it may be a potentially safe and useful alternative during operations requiring prolonged intubation and position changes.

• The results encourage a re-evaluation of standard practices for ETT cuff inflation and highlight the benefits of using saline over air in certain surgical contexts to improve patient safety and comfort.

References

1. Klompas M, Branson R, Cawcutt K, Crist M, Eichenwald EC, Greene LR, *et al.* Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 Update. Infect Control Hosp Epidemiol 2022;43:687–713.

2. Seegobin RD, van Hasselt GL. Endotracheal cuff pressure and tracheal mucosal blood flow: endoscopic study of effects of four large volume cuffs. Br Med J (Clin Res Ed) 1984;288:965–8.

3. Mehta S, Mickiewicz M. Pressure in large volume, low pressure cuffs: its significance, measurement and regulation. Intensive Care Med 1985;11:267–72.

4. Bennett MH, Isert PR, Cumming RG. Postoperative sore throat and hoarseness following tracheal intubation using air or saline to inflate the cuff—a randomized controlled trial. Anaesth Intensive Care 2000;28:408–13.

5. Porter NE, Sidou V, Husson J. Postoperative sore throat: incidence and severity after the use of lidocaine, saline, or air to inflate the endotracheal tube cuff. AANA J 1999;67:49–52.

6. El-Boghdadly K, Bailey CR, Wiles MD. Postoperative sore throat: a systematic review. Anaesthesia 2016;71:706–17.

7. Stanley TH. Nitrous oxide and pressures and volumes of high- and low-pressure endotracheal-tube cuffs in intubated patients. Anesthesiology 1975;42:637–40.

8. Tu HN, Saidi N, Leiutaud T, Bensaid S, Menival V, Duvaldestin P. Nitrous oxide increases endotracheal cuff pressure and the incidence of tracheal lesions in anesthetized patients. Anesth Analg 1999;89:187–90.

9. Bernhard WN, Yost LC, Turndorf H, Cottrell JE, Paegle RD. Physical characteristics of and rates of nitrous oxide diffusion into tracheal tube cuffs. Anesthesiology 1978;48:413–7.

10. Dullenkopf A, Gerber AC, Weiss M. Nitrous oxide diffusion into tracheal tube cuffs: comparison of five different tracheal tube cuffs. Acta Anaesthesiol Scand 2004;48:1180–4.

11. Combes X, Schauvliege F, Peyrouset O, Motamed C, Kirov K, Dhonneur G, *et al.* Intracuff pressure and tracheal morbidity: influence of filling with saline during nitrous oxide anesthesia. Anesthesiology 2001;95:1120–4.

12. Ahmad NL, Norsidah AM. Change in endotracheal tube cuff pressure during nitrous oxide anaesthesia: a comparison between air and distilled water cuff inflation. Anaesth Intensive Care 2001;29:510–4.

13. Yildirim ZB, Uzunkoy A, Cigdem A, Ganidagli S, Ozgonul A. Changes in cuff pressure of endotracheal tube during laparoscopic and open abdominal surgery. Surg Endosc 2012;26:398–401.

14. Wu CY, Yeh YC, Wang MC, Lai CH, Fan SZ. Changes in endotracheal tube cuff pressure during laparoscopic surgery in head-up or head-down position. BMC Anesthesiol 2014;14:75.

15. Meghana ND, Bharadwaj MK, Goel N, Shukla S. Endotracheal tube cuff pressure changes with pneumoperitoneum and steep head down position in patients undergoing robotic urogynecological surgeries–A prospective observational study. Journal of Indian College of Anaesthesiologists 2022;1:56.

16. Rosero EB, Ozayar E, Eslava-Schmalbach J, Minhajuddin A, Joshi GP. Effects of Increasing Airway Pressures on the Pressure of the Endotracheal Tube Cuff During Pelvic Laparoscopic Surgery. Anesth Analg 2018;127:120–5.

17. Geng G, Hu J, Huang S. The effect of endotracheal tube cuff pressure change during gynecological laparoscopic surgery on postoperative sore throat: a control study. J Clin Monit Comput 2015;29:141–4.

18. Kwon Y, Jang JS, Hwang SM, Lee JJ, Hong SJ, Hong SJ, *et al.* The change of endotracheal tube cuff pressure during laparoscopic surgery. Open Med (Wars) 2019;14:431–6.

19. Kim JB, Lee JM. A simple and widely available alternative method for endotracheal tube cuff pressure monitoring. Can J Anaesth 2018;65:956–7.

EDITORIALE MINERVA MEDICA

20. Ganigara A, Ramavakoda CY. Continuous real time endotracheal tube cuff pressure waveform. J Clin Monit Comput 2014;28:433–4.

21. Krishna SG, Ramesh AS, Jatana KR, Elmaraghy C, Merz M, Ruda J, *et al*. A technique to measure the intracuff pressure continuously: an in vivo demonstration of its accuracy. Paediatr Anaesth 2014;24:999–1004.

22. Gopalakrishnan S, Barry N, Rice J, Tobias JD. Cuffed endotracheal tubes in infants and children: a technique to continuously measure the intracuff pressure. Int J Pediatr Otorhinolaryngol 2013;77:1135–8.

23. Hagberg CA. Airway Management in the Adult. In: Wiener-Kronish JP, Eriksson LI, Fleisher LA, Gropper MA, Cohen NA, editors. Miller's Anesthesia. Ninth edition. Philadelphia: Elsevier Health Sciences; 2019.

24. Klein AA, Meek T, Allcock E, Cook TM, Mincher N, Morris C, *et al.* Recommendations for standards of monitoring during anaesthesia and recovery 2021: Guideline from the Association of Anaesthetists. Anaesthesia 2021;76:1212–23.

25. Kumar CM, Seet E, Van Zundert TC. Measuring endotracheal tube intracuff pressure: no room for complacency. J Clin Monit Comput 2021;35:3–10.

26. Zhu G, Wang X, Cao X, Yang C, Wang B, Ang Y, *et al.* The effect of different endotracheal tube cuff pressure monitoring systems on postoperative sore throat in patients undergoing tracheal intubation: a randomized clinical trial. BMC Anesthesiol 2024;24:115.

27. Mujoo SU, Tahir S, Ikram U. Changes in endotracheal tube cuff pressure with the changes in peak airway pressures during total laparoscopic hysterectomy and pelvic surgeries. A prospective and observational study. Asian J Med Sci 2023;14.

28. Narendra HR, Nerurkar A, Sasidharan S. Observational Analysis of Changes in Endotracheal Tube Cuff Pressure During Laparoscopic Surgery. Journal of Medical Academics 2020;3:46–9.

29. Chauhan P, Punera D, Palaria U, Joshi KN. Changes in endotracheal tube cuff pressure during the open and laparoscopic surgery. Indian Journal of Clinical Anaesthesia 2020;7:526–32.

30. Patel RI, Oh TH, Chandra R, Epstein BS. Tracheal tube cuff pressure. Changes during nitrous oxide anaesthesia following inflation of cuffs with air and saline. Anaesthesia 1984;39:862–4.

31. Lam F, Lin YC, Tsai HC, Chen TL, Tam KW, Chen CY. Effect of Intracuff Lidocaine on Postoperative Sore Throat and the Emergence Phenomenon: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. PLoS One 2015;10:e0136184.

32. Tanaka Y, Nakayama T, Nishimori M, Tsujimura Y, Kawaguchi M, Sato Y. Lidocaine for preventing postoperative sore throat. Cochrane Database Syst Rev 2015;2015:CD004081.

33. Mitchell V, Adams T, Calder I. Choice of cuff inflation medium during nitrous oxide anaesthesia. Anaesthesia 1999;54:32–6.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions

Ozge Siktas: conceptualization, investigation, methodology, resources. Ersel Gulec: conceptualization, methodology, formal analysis, writing - original draft preparation and reviewing and editing. Mediha Turktan: conceptualization, writing - reviewing and editing. Zehra Hatipoglu: conceptualization, writing - reviewing and editing. Demet Lafli Tunay: conceptualization, methodology, writing- reviewing and editing. Dilek Ozcengiz: conceptualization, methodology, writing - reviewing and editing. All authors read and approved the final version of the manuscript.

History

Article first published online: _____. - Manuscript accepted: May 24, 2024. - Manuscript revised: May 14, 2024. - Manuscript received: February 6, 2024.

PROOFS MINERVA MEDICA