Rev Bras Anestesiol. 2018;68(4):369–374

Sociedade Brasileira de Anestesiologia

REVISTA BRASILEIRA DE ANESTESIOLOGIA

Publicação Oficial da Sociedade Brasileira de Anestesiologia
www.sba.com.br

SCIENTIFIC ARTICLE

Comparison of endotracheal tube cuff pressure changes using air versus nitrous oxide in anesthetic gases during laparoscopic abdominal surgeries☆

Shweta Sarjerao Mogal[a,*], **Lipika Baliarsing**[a], **Raylene Dias**[b], **Pinakin Gujjar**[c]

[a] *Topiwala National Medical College and Bai Yamunabai Laxman Nair Charitable Hospital, Department of Anesthesiology, Mumbai, India*
[b] *Seth Gordhandas Sunderdas Medical College and King Edward Memorial Hospital, Department of Anesthesiology, Mumbai, India*
[c] *Topiwala National Medical College and Bai Yamunabai Laxman Nair Charitable Hospital, Department of Anesthesiology, Mumbai, India*

Received 16 November 2016; accepted 15 January 2018
Available online 14 February 2018

KEYWORDS
Anesthesia;
Endotracheal cuff pressure;
Laparoscopy;
Nitrous oxide

Abstract
Background and objectives: The purpose of this study was to compare the endotracheal tube cuff pressure changes during laparoscopic surgeries using air versus nitrous-oxide in anesthetic gas mixture; and to observe the incidences of postoperative sore throat, hoarseness and dysphagia.
Methods: Total 100 patients scheduled for elective laparoscopic abdominal surgery were allocated into two groups. Group A ($n = 50$) received air while Group N ($n = 50$) received nitrous-oxide in anesthetic gas mixture. After endotracheal intubation, cuff was inflated with air to achieve sealing pressure. Cuff pressure at baseline (sealing pressure), 30 min, 60 min and 90 min was recorded with a manometer. Incidence of sore throat, hoarseness and dysphagia was noted at the time of discharge from post-anesthesia care unit and 24 h after extubation.
Results: Cuff pressure increased from baseline in both the groups. The increase in cuff pressure in Group N was greater than that in Group A at all time points studied ($p < 0.001$). Within Group A, cuff pressure increased more at 90 min than at 30 min ($p < 0.05$). Within Group N, increase in cuff pressure was more at each time point (30, 60 and 90 min) than its previous time point ($p < 0.05$). The incidence of sore throat in post-anesthesia care unit was higher in Group N than in Group A.

☆ Study development at Department of Anesthesiology, Topiwala National Medical College and Bai Yamunabai Laxman Nair Charitable Hospital, Mumbai, India.

* Corresponding author.
E-mail: arth11.shweta@gmail.com (S.S. Mogal).

https://doi.org/10.1016/j.bjane.2018.01.015

Conclusion: Use of nitrous-oxide during laparoscopy increases cuff pressure resulting in increased incidence of postoperative sore throat. Cuff pressure should be monitored routinely during laparoscopy with nitrous-oxide anesthesia.

PALAVRAS-CHAVE
Anestesia;
Pressão do balonete endotraqueal;
Laparoscopia;
Óxido nitroso

Comparação de alterações na pressão do balonete do tubo endotraqueal usando ar versus óxido nitroso nos gases anestésicos durante cirurgias abdominais laparoscópicas

Resumo
Justificativa e objetivos: O objetivo deste estudo foi comparar as alterações na pressão do balonete do tubo endotraqueal durante cirurgias laparoscópicas usando ar *versus* óxido nitroso na mistura dos gases anestésicos e observar a incidência de dor de garganta, rouquidão e disfagia no pós-operatório.
Métodos: No total, 100 pacientes agendados para cirurgia abdominal laparoscópica eletiva foram alocados em dois grupos: Grupo A ($n = 50$) recebeu ar e Grupo N ($n = 50$) recebeu óxido nitroso na mistura de gases anestésicos. Após a intubação endotraqueal, o balonete foi insuflado com ar para obter a pressão de vedação. As pressões do balonete na fase basal (pressão de vedação), aos 30 min, 60 min e 90 min foram registradas com um manômetro. A incidência de dor de garganta, rouquidão e disfagia foi observada no momento da alta da sala de recuperação pós-anestésica e 24 horas após a extubação.
Resultados: A pressão do balonete aumentou em ambos os grupos, comparada à pressão basal. O aumento da pressão do balonete foi maior no Grupo N que no Grupo A em todos os tempos avaliados ($p < 0,001$). No Grupo A, o aumento da pressão do balonete foi maior aos 90 min que aos 30 min ($p < 0,05$). No Grupo N, o aumento da pressão do balonete foi maior em cada um dos tempos (30, 60 e 90 min) que no tempo anteriormente mensurado ($p < 0,05$). A incidência de dor de garganta na sala de recuperação pós-anestésica foi maior no Grupo N que no Grupo A.
Conclusão: O uso de óxido nitroso durante a laparoscopia aumenta a pressão do balonete, resultando em aumento na incidência de dor da garganta no pós-operatório. A pressão do balonete deve ser rotineiramente monitorizada durante a laparoscopia sob anestesia com óxido nitroso.

Introduction

Laparoscopic surgeries are commonly preferred now-a-days over open abdominal surgeries because of the benefits like less incisional pain, quicker recovery and shorter hospital stay. General anesthesia with endotracheal intubation and controlled ventilation is considered as a safe technique of anesthesia for laparoscopy. Cuffed endotracheal tubes (ETT) are used to achieve a seal between the cuff and trachea with a pressure great enough to prevent aspiration but not so high that the tracheal blood flow will be impeded. Ischaemia of tracheal wall occurs when pressure against the tracheal wall from the hyper-inflated cuff exceeds the pressure in the capillary blood supply. Tracheal mucosal perfusion can be impaired by cuff pressure greater than 30 cmH_2O and thus patient can experience sore throat, hoarseness and dysphagia.[1,2] It has been reported that laparoscopy causes an increase in endotracheal tube cuff pressure and sore throat in postoperative period.[3] Intracuff pressure can also be affected by the type of anesthetic agent. Nitrous oxide (N_2O) is known to diffuse into the endotracheal tube cuffs.[4] There are studies which have shown that during general anesthesia with N_2O, intracuff pressure increases causing increase in tracheal injury and sore throat.[1,5] However, in the modern era with emphasis on enhanced recovery after surgery, N_2O remains a valuable option in view of its effect on recovery and benefits in general anesthesia.[6–8] Also, in Indian set-up, many hospitals and nursing homes have limited availability of air as an anesthetic gas. N_2O is freely available there and thus commonly used during laparoscopy. The effects of N_2O use during laparoscopy on cuff pressure changes have not been studied. The purpose of this study was to evaluate changes in endotracheal tube cuff pressure during laparoscopy using air versus N_2O in balanced general anesthesia. We aimed to observe the incidences of postoperative laryngo tracheal complaints and thus to assess the necessity of monitoring endotracheal tube cuff pressure during laparoscopy with N_2O anesthesia.

Methods

This prospective randomized controlled double-blind study was conducted after obtaining institutional ethics committee approval and written informed consent from patients. We studied total 100 patients and randomized them in two groups by computer generated randomization table. Group A received oxygen-air while Group N received oxygen-N_2O while providing Intermittent Positive Pressure Ventilation (IPPV) for general anesthesia. Patients were unaware of their group allocation. All non-smoking patients between 18–60 years of age of either sex with ASA (American Society of Anesthesiologists) physical status I or II undergoing elective laparoscopic abdominal surgery were included in the study. Exclusion criteria included the following: obese patients (BMI > 35), smokers, patients with tracheotomy, patients with laryngeal disease or surgery, patients with anticipated difficult intubation and patients with past history of nausea and vomiting.

After confirming Nil By Mouth (NBM) status, patients were placed in supine position in the operating room. ASA standard monitoring devices were applied. Intravenous (iv) infusion with crystalloid solution was started. Patients were premedicated with intravenous midazolam 0.03 mg.kg^{-1} and intravenous ondansetron 4 mg was given as antiemetic prophylaxis. This was followed by intravenous fentanyl 2 μg.kg^{-1}. After pre-oxygenation with 100% oxygen for 3 min, general anesthesia was induced with intravenous thiopentone sodium (5–7 mg.kg^{-1}). Neuromuscular block was achieved with intravenous vecuronium bromide (0.1 mg.kg^{-1}). Tracheal intubation was performed with Portex® ETT (internal diameter 7 mm for females and 8 mm for males) having high-volume, low-pressure cuff (Smiths medical, Hythe, UK). Black line at vocal cords and bilateral equal air entry was confirmed. ETT cuff was inflated with air with the help of a sterile 10 mL syringe, to achieve an adequate cuff seal so that there was no audible leak at peak inspiratory pressures. After achieving adequate cuff pressure, there was no manipulation during the anesthetic procedure. To measure endotracheal tube cuff pressure, a Portex® manometer (Smiths medical, Hythe, UK) was connected to the endotracheal tube pilot balloon. The baseline sealing pressure was recorded in both the groups following intubation after achieving adequate cuff seal. Both the groups were provided with balanced general anesthesia. Group A received oxygen and air (50:50) while Group N received oxygen and nitrous oxide (50:50) while providing positive pressure ventilation. Mechanical ventilation was controlled and adapted to maintain end-tidal carbon-dioxide ($ETCO_2$) between 30 and 35 mmHg. Nasogastric tube was inserted in both the groups before trocar insertion. Anesthesia was maintained with intravenous propofol (4–6 mg.kg^{-1}.h^{-1}), intermittent doses of intravenous fentanyl (1–2 μg.kg^{-1}) and intravenous vecuronium (0.02 mg.kg^{-1}). Maintenance intravenous fluids were given according to the requirement. Endotracheal tube cuff pressure was measured subsequently at 30 min, 60 min and 90 min following baseline measurement in both the groups by an anesthesiologist not involved in the study. At the end of surgery, anesthesia was reversed with intravenous glycopyrrolate (8 μg.kg^{-1}) and intravenous neostigmine (0.05 mg.kg^{-1}). Nasogastric tube was removed. Mechanical ventilation was maintained until patients started breathing spontaneously. After full reversal of neuromuscular blockade, return of reflexes and spontaneous ventilation and ability to follow verbal commands, endotracheal tube cuff was totally deflated and patients were extubated. Before extubation, 100% oxygen was provided. Patients were shifted to Post Anesthesia Care Unit (PACU) for observation. Patients were asked about sore throat, hoarseness and dysphagia at the time of discharge from PACU and after 24 h of extubation by an independent observer unaware of patient allocation groups.

Sample size was calculated from a study[9] by difference in mean method at 90% power and 5% α error. Minimum sample size per group was found to be 30. We decided to take sample size of 50 per group. Data analysis was done with the help of SPSS Software version 15. Quantitative data was presented with the help of mean, Standard Deviation (SD), median and Inter Quartile Range (IQR); comparison between study groups was done with the help of unpaired *t*-test or Mann–Whitney test as per the results of normality test. Repeated measures analysis of variance was used to compare variables at each time point within groups, and post hoc analysis was performed using Tukey's test. Qualitative data was presented with the help of frequency and percentage table, association among study groups was assessed with the help of Chi-Square test.

p-value less than 0.05 was considered as significant.

Results

Each group consisted of 50 patients. The groups are comparable with respect to age, sex and surgical procedures (Table 1). The cuff pressures in both the groups are presented in Fig. 1. The postoperative adverse events are presented in Table 2.

Discussion

The purpose of the cuff of an endotracheal tube is to provide a seal between the tube and tracheal wall. This seal ensures

Table 1 Demographic data.

	Group A ($n = 50$)	Group N ($n = 50$)
Age (years)	38.97 ± 12.40	38.83 ± 13.19
Sex		
Male	11	10
Female	39	40
Surgical procedures		
1. Laparoscopic cholecystectomy	37	31
2. Diagnostic laparoscopy	8	9
3. Laparoscopic incisional hernia repair	1	2
4. Laparoscopic inguinal hernia repair	3	2
5. Laparoscopic appendicectomy	1	6

Data presented as mean ± SD or number.

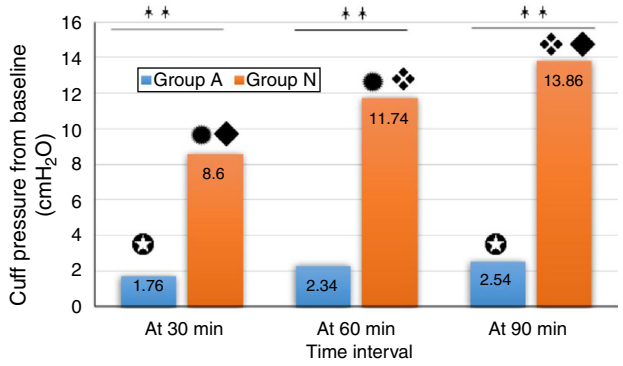

Figure 1 Comparison of cuff pressure changes from baseline at different time points in study groups. Similar symbols represent significant difference between two time points within a group ($p < 0.05$). ** Represents significant difference between Group A and Group N at a given time point ($p < 0.001$).

Table 2 Percent incidence of postoperative complications in study groups.

	Group A	Group N
Hoarseness		
PACU	10%	16%
After 24 h	0%	2%
Sore throat		
PACU[a]	12%	32%
After 24 h	0%	2%
Dysphagia		
PACU	4%	12%
After 24 h	0%	0%

PACU, Post Anesthesia Care Unit.
[a] Represents difference is significant between two groups at $p < 0.05$.

positive pressure ventilation by avoiding gas leaks and also prevents passage of pharyngeal contents into the trachea. However, high cuff pressure can cause damage to trachea by compromising tracheal mucosal perfusion. Cuff pressure of 20–30 cmH_2O is accepted as an ideal range that would prevent aspiration without impairing tracheal mucosal blood flow.[10]

Our data show that the cuff pressure increased from baseline in both groups. This can be explained by laparoscopy induced rise in endotracheal tube cuff pressure. Studies have shown that pneumoperitoneum and the resultant rise in airway pressure during laparoscopy increases endotracheal tube cuff pressure and occurrence of postoperative sore throat.[3,11] In above studies the increase in cuff pressure was noted few minutes after pneumoperitoneum was achieved, but the comparison of changes in cuff pressure at different time points within the group was not done. In our study, although N_2O was not used in Group A, cuff pressure increased with increasing time period. The increase in cuff pressure at 90 min was greater than that at 30 min in Group A ($p < 0.05$) (Fig. 1). A future research is desired to understand more possible mechanisms of increase in cuff pressure during laparoscopy especially when the duration of laparoscopy is extended.

Our study also shows that the increase in cuff pressure in Group N was greater than the increase in cuff pressure in Group A at all time points studied ($p < 0.001$) (Fig. 1). Also, in Group N, cuff pressure increased significantly at every 30 min throughout the procedure ($p < 0.05$). Thus, the cuff pressure in nitrous oxide group had a rising trend which was higher than the rising trend of cuff pressure in Group A (Fig. 1). This excessive increase in cuff pressure in Group N can be explained by the permeability of cuff to N_2O. The relation between N_2O anesthesia and increased intracuff pressure has been shown by many studies.[1,4,5,9,12] Air in endotracheal tube cuff contains nitrogen which has low blood solubility. The much greater solubility of N_2O in blood induces a large pressure gradient between blood and air-filled cuff. Nitrous oxide diffuses more rapidly into the cuff than nitrogen diffuses out of the cuff. This causes cuff volume and pressure to rise. Thus, laparoscopy induced an increase in cuff pressure in both of our study groups; but the use of N_2O in Group N led to excessive rise of cuff pressure in this group and the significant difference in cuff pressure between two groups.

The effect of increased cuff pressure on postoperative laryngo-tracheal complications were considered. In this study, incidence of hoarseness and dysphagia was similar between two groups. These symptoms may not be related to high cuff pressure.[1] However, both the groups experienced sore throat in PACU (12% in Group A, 32% in Group N). This incidence in Group N was higher than in Group A ($p < 0.05$). The incidence of sore throat after 24 h was low and similar for both the groups. The higher incidence of sore throat in PACU in Group N can be explained by the significant rise in cuff pressure due to N_2O diffusion into the cuff. The effect of N_2O induced increased cuff pressure on tracheal mucosal erosions and postoperative sore throat has been shown by a study in 2001.[1] We studied the effect of cuff pressure on laryngo-tracheal complications when laparoscopy is combined with N_2O anesthesia. According to our data, the occurrence of sore throat in laparoscopy is significantly increased when N_2O is used for anesthesia.

Mucosal perfusion of airway is impaired when cuff pressure exceeds 30 cmH_2O.[2] In our study, 16 patients in Group N and 6 patients in Group A had sore throat in PACU. Out of these, cuff pressure of 30 cmH_2O was exceeded in 13 patients in Group N and 4 patients in Group A. Effect of maintaining low cuff pressure during anesthesia on reducing the incidence of postoperative sore throat has been shown by some studies.[13,14] Our study thus indicates that the cuff pressure should be continuously monitored and decreased if it exceeds 30 cmH_2O during laparoscopy, especially when N_2O is used.

Although there are concerns regarding intraoperative bowel distension, operating conditions and postoperative emesis when N_2O is used during laparoscopy, studies have shown that N_2O has no effects clinically in terms of bowel distension and technical difficulties during laparoscopic cholecystectomy.[15,16] Also, the increased incidence of postoperative nausea and vomiting caused by N_2O can be

prevented by use of prophylactic antiemetics and maintenance with propofol.[8,17] N_2O has benefits like effective analgesia, reduced incidence of intraoperative awareness, reduced requirement of more potent anesthetics and thus limiting cardiorespiratory side effects.[8,18] Considering this and the free availability of N_2O in Indian set up, it is commonly used during laparoscopy. Our study identifies the need for intraoperative cuff pressure monitoring in this area.

There are some limitations to this study. Firstly, we did not measure the grade of neuromuscular blockade at the moment of intubation. This could have impacted postoperative laryngopharyngeal events. It has been demonstrated that using a relaxant improves quality of tracheal intubation and decreases postoperative hoarseness and vocal cord sequelae.[19] Although neuromuscular monitoring improves intubating conditions, however, tracheal intubation at maximum intensity of neuromuscular block was not associated with a decrease in vocal cord injuries.[20] Secondly, patient position was not taken into consideration as there are multiple types of laparoscopic procedures involved in this study. Endotracheal tube cuff pressure is affected by changes in position of the patient. Wu et al. found that the cuff pressure increases in laparoscopy in head-down position.[21] It has been also found that the clinically relevant changes in cuff pressure occur by different body positions in critically ill patients receiving mechanical ventilation.[22] Thirdly, intra-abdominal pressure and airway pressures were not monitored. Pneumoperitoneum reduces respiratory system compliance and increases airway pressure.[23] A study has shown that this pneumoperitoneum induced increase in airway pressure causes cuff pressure to rise which is associated with higher incidence of postoperative sore throat.[11] Our data suggest that cuff pressure and incidence of postoperative sore throat increases significantly when N_2O is used during laparoscopy. However, airway pressure and intra-abdominal pressure were not noted at the moment of cuff pressure measurement. Fourthly, the intensity of postoperative complications was not measured. However, even if the intensity of sore throat may vary, its occurrence should not be neglected because of its association with the underlying tracheal lesions caused by excessive cuff pressure.[1]

Conclusion

Laparoscopy induced increase in endotracheal tube cuff pressure is exaggerated by N_2O. Use of N_2O in anesthetic gas mixture during laparoscopy is associated with progressive increase in cuff pressure resulting in increased incidence of postoperative sore throat. Cuff pressure monitoring should be performed routinely during laparoscopy with N_2O anesthesia.

Clinical trial registry

The study was not registered with Clinical Trial Registry.

Conflicts of interest

The authors declare no conflicts of interest.

References

1. Combes X, Schauvliege F, Peyrouset O, et al. Intracuff pressure and tracheal morbidity: influence of filling with saline during nitrous oxide anesthesia. Anesthesiology. 2001;95:1120–4.
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. Yildirim ZB, Uzunkoy A, Cigdem A, et al. Changes in cuff pressure of endotracheal tube during laparoscopic and open abdominal surgery. Surg Endosc. 2012;26:398–401.
4. Stanley TH, Kawamura R, Graves C. Effects of nitrous oxide on volume and pressure of endotracheal tube cuffs. Anesthesiology. 1974;41:256–62.
5. Tu HN, Saidi N, Leiutaud T, et al. Nitrous oxide increases endotracheal cuff pressure and the incidence of tracheal lesions in anesthetized patients. Anesth Analg. 1999;89:187–90.
6. Joshi GP. Rapid recovery from ambulatory surgery: the new paradigm in ambulatory anesthesia. IARS Review Course Lectures; May 2013.
7. Peyton PJ, Chao I, Weinberg L, et al. Nitrous oxide diffusion and the second gas effect on emergence from anesthesia. Anesthesiology. 2011;114:596–602.
8. Hopkins PM. Nitrous oxide: a unique drug of continuing importance for anaesthesia. Best Pract Res Clin Anaesthesiol. 2005;19:381–9.
9. Braz JR, Navarro LH, Takata IH, et al. Endotracheal tube cuff pressure: need for precise measurement. Sao Paulo Med J. 1999;117:243–7.
10. Sengupta P, Sessler DI, Maglinger P, et al. Endotracheal tube cuff pressure in three hospitals, and the volume required to produce an appropriate cuff pressure. BMC Anesthesiol. 2004;4:8.
11. 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.
12. Braz JR, Volney A, Navarro LH, et al. Does sealing endotracheal tube cuff pressure diminish the frequency of postoperative laryngotracheal complaints after nitrous oxide anesthesia? J Clin Anesth. 2004;16:320–5.
13. Suzuki N, Kooguchi K, Mizobe T, et al. Postoperative hoarseness and sore throat after tracheal intubation: effect of a low intracuff pressure of endotracheal tube and the usefulness of cuff pressure indicator. Masui. 1999;48:1091–5.
14. Mandoe H, Nikolajsen L, Lintrup U, et al. Sore throat after endotracheal intubation. Anesth Analg. 1992;74:897–900.
15. Abballe C, Camaioni D, Mascaro A, et al. Anesthesia for laparoscopic cholecystectomy: the use of nitrous oxide in the anesthetic mixture. G Chir. 1993;14:493–5.
16. Taylor E, Feinstein R, White PF, et al. Anesthesia for laparoscopic cholecystectomy: is nitrous oxide contraindicated? Anesthesiology. 1992;76:541–3.
17. Fernández-Guisasola J, Gómez-Arnau JI, Cabrera Y, et al. Association between nitrous oxide and the incidence of postoperative nausea and vomiting in adults: a systematic review and meta-analysis. Anaesthesia. 2010;65:379–87.
18. Schönherr ME, Hollmann MW, Graf B. Nitrous oxide. Sense or nonsense for today's anaesthesia. Anaesthesist. 2004;53:796–812.
19. Mencke T, Echternach M, Kleinschmidt S, et al. Laryngeal morbidity and quality of tracheal intubation: a randomized controlled trial. Anesthesiology. 2003;98:1049–56.
20. Mencke T, Echternach M, Plinkert PK, et al. Does the timing of tracheal intubation based on neuromuscular monitoring

decrease laryngeal injury? A randomized, prospective, controlled trial. Anesth Analg. 2006;102:306–12.
21. Wu CY, Yeh YC, Wang MC, et al. Changes in endotracheal tube cuff pressure during laparoscopic surgery in head-up or head-down position. BMC Anesthesiol. 2014;14:75.
22. Lizy C, Swinnen W, Labeau S, et al. Cuff pressure of endotracheal tubes after changes in body position in critically ill patients treated with mechanical ventilation. Am J Crit Care. 2014;23:e1–8.
23. Rauh R, Hemmerling TM, Rist M, et al. Influence of pneumoperitoneum and patient positioning on respiratory system compliance. J Clin Anesth. 2001;13:361–5.