Clinical Trial/Experimental Study

Medicine®

OPEN

Changes in tapered endotracheal tube cuff pressure after changing position to hyperextension of neck

A randomized clinical trial

Ji-Hoon Park, MD, Hyo-Jin Lee, MD, Sou Hyun Lee, MD, Ji Seob Kim, MD*

Abstract

Background: Endotracheal tube (ETT) with a tapered-shaped cuff had an improved sealing effect when compared to ETTs with a conventional cylindrical-shaped cuff. Positional change and neck movement typically displace an ETT and change the intracuff pressure. The aim of the current study was to compare the ETT cuff pressure in the TaperGuard ETT vs the conventional ETT after a change from the supine, neutral position to the extension of the neck and semi-Fowler position for thyroid surgery.

Methods: This prospective, randomized clinical trial included 50 patients undergoing thyroidectomy. Patients were randomly allocated into one of the 2 groups: tracheal intubation with the TaperGuard ETT or with a conventional ETT. The ETT cuff was inflated with air and the ETT cuff pressure was set initially at 20 cmH_2O using a calibrated cuff manometer. ETT cuff pressure and distance from carina to ETT tip were measured at supine and semi-Fowler positions with neck extension.

Results: After the position change, the ETT tip migrated cephalad and cuff pressure increased in the majority of cases. ETT cuff pressure was significantly higher in the TaperGuard group than the conventional group (28.0 ± 6.6 cmH_2O and 22.8 ± 4.5 cmH_2O, respectively, $P = .001$). The degree of cephalad displacement of the ETT tip was comparable between the 2 groups (19.4 ± 6.31 mm in TaperGuard group and 21.9 ± 6.9 mm in conventional group, $P = .12$).

Conclusions: After the position change from supine to hyperextension of the neck, the ETT cuff pressure was higher in the TaperGuard ETT than in the conventional ETT, although the extent of displacement of the ETT was comparable between the 2 groups.

Abbreviations: ETT = endotracheal tube, ICU = intensive care unit.

Keywords: cuff pressure, endotracheal tube, extension of neck, tapered-shaped cuff

1. Introduction

Appropriate endotracheal tube (ETT) cuff pressure is required for positive pressure ventilation during general anesthesia. Appropriate cuff pressure is 20 to 30 cmH_2O, and when the pressure is low, adequate ventilation may be impaired due to gas leakage.[1–4] Conversely, when the pressure is high, the airway mucosa may be pressed upon which can cause various complications.[1,4,5] The ETT cuff pressure can be affected by several issues such as patient factors (e.g., differences in the size of the trachea and the position of the ETT cuff), anesthetic factors (e.g., intraoperative use of high airway pressure and nitrous oxide), and cuff related factors (e.g., differences in cuff compliance, diameter, thickness, and geometry).[6–13]

Thyroidectomy is a widely performed procedure requiring a specific surgical position that can facilitate exposure of the anterior neck. A roll can be placed transversely under the scapulae to achieve neck extension. However, this position can affect the ETT cuff pressure during surgery and increase postoperative airway complications.[14]

Use of an endotracheal tube with a tapered-shaped cuff (TaperGuard™ ETT, Covidien, Athlone, Ireland) improved the sealing effect compared to the ETT with a conventional cylindrical-shaped cuff (Mallinckrodt ETT, Covidien, Athlone, Ireland).[15] Lower cuff pressure was required with TaperGuard ETT to obtain an adequate seal compared to conventional ETT.[12] However, in some recent studies, TaperGuard ETT has been shown to increase the cuff pressure more than the conventional ETT after a position change during surgery.[16,17] In prior studies, the surgical position was either lateral frank position or supine position with lateral rotation of head. Such position changes were related to lateral movements of the neck

Editor: Ibtesam Hilmi.

This research was supported by the Keimyung University Research Grant No: 20190241.

The authors have no conflicts of interests to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Department of Anesthesiology and Pain Medicine, Keimyung University Dongsan Medical Center, Daegu, Korea.

** Correspondence: Ji Seob Kim, Department of Anesthesiology and Pain Medicine, Keimyung University Dongsan Medical Center, Daegu, Korea (e-mail: demiandew@naver.com).*

How to cite this article: Park JH, Lee HJ, Lee SH, Kim JS. Changes in tapered endotracheal tube cuff pressure after changing position to hyperextension of neck: a randomized clinical trial. Medicine 2021;100:29(e26633).

Received: 1 February 2020 / Received in final form: 18 December 2020 / Accepted: 23 June 2021

http://dx.doi.org/10.1097/MD.0000000000026633

and body. However, there are only a few studies in which is the cuff pressure change following anterior-posterior movement during the surgery is compared.

The aim of the current study was to compare the ETT cuff pressure in the TaperGuard ETT to the conventional ETT after a change from the supine, neutral position to neck extension and semi-Fowler position for thyroid surgery. In addition, we compared the extent of ETT displacement by measuring the distance from carina to the ETT tip.

2. Methods

2.1. Study population

This study was approved by the Institutional Review Board of Keimyung University, Dongsan Medical Center (IRB ref No: DSMC2016-05-032-001) and registered at clinicalTrials.gov (NCT02949856). A total of 50 patients undergoing open thyroidectomy with American Society of Anesthesiologists physical status I-III with ages ranging from 18 to 70 years were included. Exclusion criteria were patients with difficult airway, history of previous neck surgery, limitation of neck motion, and BMI of greater than 35 kg/m^2. Informed consent was obtained from all patients.

2.2. Study procedures and anesthesia

Patients were randomly allocated into one of the 2 groups: tracheal intubation with the TaperGuard ETT (n = 25) or with a conventional ETT (n = 25) using a computer-generated randomization program. The randomization process was performed by a resident who was not involved in this study.

The patients were given 7.5 mg of midazolam orally the night before surgery. One hour prior to surgery, 0.2 mg of glycopyrrolate and 2 to 2.5 mg of midazolam were administered by intramuscular injection premedication. In the operating room, patients were monitored using noninvasive arterial blood pressure, pulse oximetry, and electrocardiography (Tram-rac 4A, GE Medical System, Milwaukee, WI, USA). Bispectral index scale monitoring (bispectral index scale VISTA monitoring system, Aspect Medical Systems Inc., Norwood, MA, USA) was used to monitor the depth of anesthesia. The patients' heads were positioned on a 5 cm high head rest. General anesthesia was induced by propofol 2 mg/kg, rocuronium 0.8 mg/kg, with target controlled infusion of remifentanil 4 to 5 ng/mL (Orchestra Base Primea, Fresenius Kabi, Brezins, France). Anesthesia was maintained with 1.5% to 3% vol sevoflurane and 2.5 L/min of an oxygen-air mixture. Train-of-four (TOF-Watch, Organon Ireland Ltd., Dublin, Ireland) was used through the ulnar nerve stimulation for neuromuscular monitoring and determining the need for an additional dose of rocuronium. Volume-controlled ventilation with a tidal volume of 8 mL/kg predicted by body weight and an adequate respiratory rate were set to maintain normocapnia in patients.

Endotracheal intubation was performed using ETT with an internal diameter of 7.0 mm for women and 7.5 mm for men, respectively. ETT was positioned so that the vocal cords were located between the 2 markers on the tube shaft. The ETT was fixed with tape at the right corner of the mouth. The ETT cuff was inflated with air and the ETT cuff pressure was set initially at 20 cmH_2O using a calibrated cuff manometer (Mallinckrodt™ hand pressure gauge, Covidien, Neustadt an der Donau, Germany) in the supine, neutral position. Subsequently, the distance from the carina to ETT tip was measured by means of fiberoptic bronchoscope (LF-GP, Olympus, Tokyo, Japan) using the drawback technique by Weiss et al.[18] Position change from the supine, neutral position to the thyroidectomy position was achieved; neck extension by placing thyroid pillow (Emtas, Seoul, Korea) and semi-Fowler position by adjusting the surgical table. During the position change, the ETT was held immobile by the anesthesiologist to prevent unintentional displacement.

After the position change, the ETT cuff pressure and the distance from the carina to ETT tip were measured again using the same method. The ETT cuff pressure was readjusted to 20 cmH_2O as necessary.

2.3. Outcomes measurements

The overall incidence of postoperative airway complications such as sore throat, hoarseness, and dysphagia were evaluated and the severity of postoperative sore throat were graded immediately after the operation at the post-anesthesia care unit, and at 12 hours and 24 hours postoperatively in the general ward. A sore throat was evaluated as follows: Severe manifestation of hoarseness or change in vocalization that is related to throat discomfort; moderate complaint of POST spontaneously; mild complaint of POST only when asking; or the absence of a sore throat.

The primary endpoint of the current study was the cuff pressure change after position change. The second endpoint was the ETT displacement after position change.

2.4. Statistical analysis

According to a previous study,[16] the mean (SD) difference in cuff pressure between 2 ETTs was 6 (7) after position change. Assuming that the difference and SD were equal to the previous study, 25 patients would be needed in each group ($\alpha = 0.05$, $\beta = 0.2$, dropout rate 10%). Statistical analysis was performed using SPSS 23.0 for Windows (IBM, Chicago, IL). The cuff pressure changes and displacement of the ETT tip were compared using independent *t*-tests, the overall incidence of postoperative airway complication was compared using a Chi-Squared test, and the severity of sore throat was compared using independent *t*-test or Mann–Whitney *U* test.

3. Results

A total of 54 patients for open thyroidectomy from July 2016 to April 2017 were enrolled. Four patients were excluded from the study, 2 as they did not meet inclusion criteria and 2 who declined to participate. The remaining 50 patients were randomly placed in the TaperGuard group or conventional group. One patient of each group was dropped out due to failure of tracheal intubation at first attempt (Fig. 1).

Demographic and anesthetic data regarding patients' clinical characteristics, duration of surgery and anesthesia, and tidal volumes were comparable between the 2 groups (Table 1).

No air leakage occurred after cuff inflation or position change in either group. After the position change from the supine, neutral position to the thyroidectomy position, the ETT cuff pressure was significantly higher in TaperGuard group compared to the conventional group (28.0 ± 6.6 cmH_2O and 22.8 ± 4.5 cmH_2O, respectively, $P = .001$) (Table 2). The incidence of cuff pressure

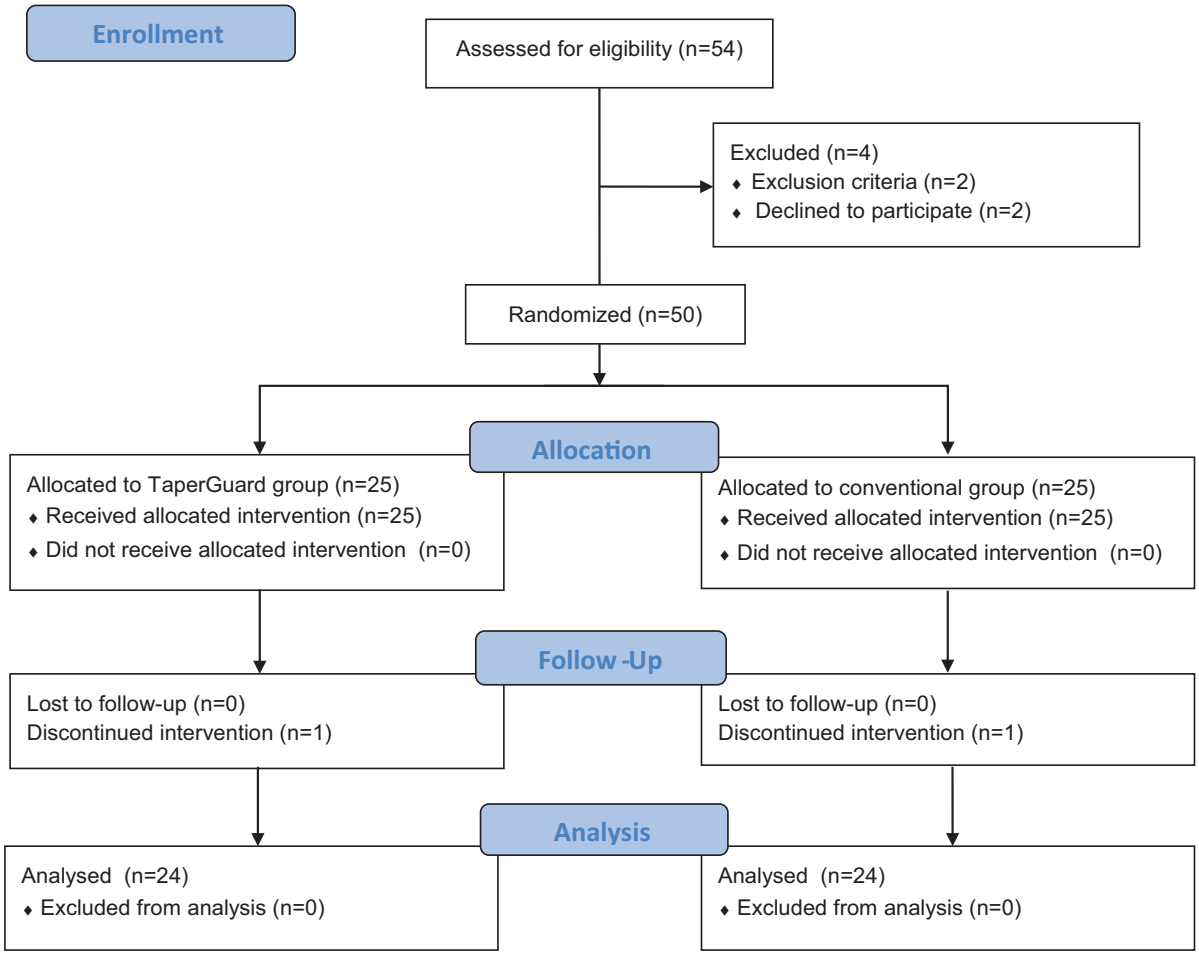

Figure 1. CONSORT diagram for the current study. Fifty patients were randomly placed in one of 2 groups, 48 of which were included in the final analysis.

Table 1

Demographic and anesthesia Data.

	TaperGuard group (n=24)	Conventional group (n=24)
Age (yr)	41.5±14.2	43.0±12.5
Sex (F/M)	20/4	21/3
Height (cm)	158.9±8.4	157.4±5.0
Weight (kg)	61.7±6.7	59.7±8.2
ASA class I/II/III	18/5/1	18/6/0
Duration of anesthesia (min)	95.1±16.7	92.6±15.3
Duration of operation (min)	62.6±14.7	61.8±14.5
Amount of infused remifentanil (μg)	528±143	500±122
Cormack-Lehane grade 1/2/3	9/13/2	8/13/3
Intubation time (sec)	29.5±4.8	30.6±8.5
Tidal volume (mL)	483±56	461±52
Peak airway pressure (cmH_2O)	15.7±2.2	15.3±2.6

Values are presented as mean±standard deviation, or number of patients. ASA = American Society of Anesthesiologists.

Table 2

Cuff pressure change and tube displacement after position change.

	TaperGuard group (n=24)	Conventional group (n=24)	*P* value
ETT cuff pressure (cmH_2O)	28.0±6.6	22.8±4.5	.001
Cuff pressure >30 cmH_2O	6 (25%)	0 (0%)	.01
ETT cephalad displacement (mm)	19.4±6.3	21.9±6.9	.12

Values are presented as mean±standard deviation, or number of cases (%). ETT = endotracheal tube.

Table 3

Overall incidence of postoperative airway complication.

	TaperGuard group (n = 24)	Conventional group (n = 24)	*P* value
Sore throat	16 (67%)	15 (63%)	.763
Hoarseness	9 (38%)	10 (42%)	.768
Dysphagia	2 (8%)	3 (12%)	.999

Values are presented as number of patient (%).

elevation above 30 cmH_2O was significantly higher in TaperGuard group compared to conventional group (6 patients and 0 patients, respectively, $P = .01$) (Table 2).

The extent of cephalad displacement of ETT tip after the position change from the supine, neutral to the thyroidectomy position was comparable between the 2 groups (19.4 ± 6.31 mm in TaperGuard group and 21.9 ± 6.9 mm in conventional group, $P = .12$) (Table 2).

There was no significant difference in the overall incidence of postoperative airway complications and severity of postoperative sore throat between the 2 groups (Tables 3 and 4).

4. Discussion

Position changes in intubated patients alter the ETT position in the trachea, resulting in changes to cuff pressure.[19–21] ETT cuff pressure changes in response to movement as the trachea is not cylindrical in shape and the inner diameter changes along its course.[22–25] The general position for thyroidectomy involves neck extension and the semi-Fowler position. While the semi-Fowler position does not alter ETT cuff pressure, neck extension causes cephalad migration of the ETT and increases ETT cuff pressure.[19,21] Kim et al[16] described that when the ETT migrates cephalad adjacent to narrower and less compliant airway structures, such as the cricoid cartilage, the cuff is compressed, and the cuff pressure is elevated according to Boyle's law, that is, if the temperature and amount of gas remain unchanged within a closed system, the pressure and volume of a gas are inversely proportional. In the present study, the cuff pressure also increased as the ETT moved toward vocal cord in both groups. While the extent of ETT migration was comparable between the 2 groups, the cuff pressure was significantly increased in the TaperGuard ETT group. Since the various factors that can affect the cuff pressure are the same, this result implies that the difference in the cuff pressure increment is not due to displacement of the ETT but rather due to geometric difference of the cuff.[16] The conical shape of the TaperGuard tube cuff, the smaller cuff volume and the narrower tracheal contact area of the TaperGuard tube may result in higher cuff pressure related to ETT movement.

The TaperGuard ETT reduces the area of tracheal impact and the cuff pressure required to obtain an adequate seal when compared to a cylindrical ETT.[12,15,26,27] A recent study reports that a tapered cuff reduces the incidence and severity of postoperative sore throat and hoarseness.[28] This outcome was obtained by maintaining the cuff pressure at 25 cmH_2O upon rechecking every 30 minutes. As intraoperative position change is common, ETT cuff pressure may not be constant in throughout the surgery, resulting in even greater pressure change using the TaperGuard ETT.[16,17] Even in short surgical procedures, it is necessary to readjust the cuff pressure appropriately during surgery.

Intubation is commonly performed in the intensive care unit (ICU) as well as in the operation room. Compared to the operating room, patients in the ICU have a longer duration of intubation, so it is necessary to maintain appropriate cuff pressure within a stricter range. Position changes can often occur during procedures such as central vein cannulation, wound dressing, and log roll for prevention of pressure ulcers. Lizy et al[21] studied the relationship between various position and conventional ETT cuff pressure in the ICU and reported that the cuff pressure increased in many positions. Since the TaperGuard ETT reduces microaspiration of subglottic secretions which is considered the major pathogenic mechanism of ventilator associated pneumonia,[15,29] it can be widely used in the ICU. More attention should be paid to the use of the TaperGuard ETT

Table 4

Severity of postoperative sore throat.

	TaperGuard group (n = 24)	Conventional group (n = 24)	*P* value
At PACU			.999
None	9 (33%)	9 (38%)	
Mild	9 (42%)	10 (42%)	
Moderate	4 (17%)	3 (12%)	
Severe	2 (8%)	2 (8%)	
Postoperative 12 h			.999
None	9 (29%)	10 (25%)	
Mild	8 (42%)	7 (46%)	
Moderate	4 (17%)	5 (21%)	
Severe	3 (12%)	2 (8%)	
Postoperative 24 h			.999
None	12 (50%)	13 (54%)	
Mild	10 (42%)	9 (38%)	
Moderate	2 (8%)	1 (4%)	
Severe	0 (0%)	1 (4%)	

Values are presented as number of patient (%). PACU = postanesthesia care unit.

in the ICU as position change may result in greater increment of cuff pressure compared to the conventional ETTs.[16,17]

There is a close relationship between elevated ETT cuff pressure and postoperative airway complications such as sore throat, hoarseness, and cough.[4] When the pressure is above 30 cmH_20, the blood supply to the tracheal mucosa begins to decrease and causes injury.[4,22] Even in procedures with short duration, high ETT cuff pressure has been reported to result in postoperative complications.[4] In the present study, there were 6 patients whose cuff pressure elevated above 30 cmH_2O in the TaperGuard group compared to 0 in the conventional group. However, the incidence of postoperative airway complications and severity were comparable between the 2 groups. This occurred as after position change for thyroidectomy, the ETT tip placement and the cuff pressure were measured and then the cuff pressure was readjusted to 20 cmH_2O. While the current study showed comparable incidence between the 2 groups, a higher incidence of postoperative airway complications occurred (sore throat 67% vs 63%). It is postulated that this is due to the thyroidectomy procedure itself. Postoperative sore throat is a common airway complication of patients undergoing thyroidectomy, with an incidence of 62% to 84%.[30–32]

This study had several limitations. First, investigators were not blind to conditions, which may have introduced a possible source of bias. Blinding was impossible in this study because the type of ETT was difficult to keep hidden from the investigators. Second, postoperative complications were comparable between both groups. It was difficult to explain the relationship between cuff pressure and complications since the study protocol was to readjust the cuff pressure. Moreover, complications of thyroidectomy itself had similar postoperative effects such as sore throat, making it difficult to clarify the relationship between the type of ETT cuff and complications. Third, the initial cuff pressure was set to 20 cmH_2O which was the conventional pressure and did not reflect the characteristics of the TaperGuard tube. Therefore, it may have influenced the change in cuff pressure after the position change. Further research is needed on the appropriate cuff pressure considering the shape of the TaperGuard tube. Finally, this study was performed in a population of patients who were Asian, which limited the ability to extrapolate the results to other racial populations. Previous reports have shown that the intraluminal diameter of the subglottis and upper trachea differ between Indian and Western populations.[33]

In conclusion, after the change from the supine, neutral position to the thyroidectomy position the ETT tip migrated cephalad and ETT cuff pressure increased in most cases. The increase in cuff pressure was significantly higher in the TaperGuard ETT than in the conventional cylindrical ETT. This study suggests that cuff pressure monitoring is necessary after position change during thyroid surgery, especially in when using tapered-shaped cuff type ETT.

Author contributions

Conceptualization: Ji Seob Kim.
Data curation: Ji Seob Kim.
Formal analysis: Ji-Hoon Park, Ji Seob Kim.
Funding acquisition: Ji Seob Kim.
Investigation: Ji-Hoon Park, Sou Hyun Lee, Ji Seob Kim, Hyo-Jin Lee.
Methodology: Ji Seob Kim.
Project administration: Ji-Hoon Park, Ji Seob Kim.
Resources: Ji-Hoon Park, Ji Seob Kim.
Software: Ji-Hoon Park, Sou Hyun Lee, Ji Seob Kim.
Supervision: Ji Seob Kim.
Validation: Ji-Hoon Park, Ji Seob Kim.
Visualization: Ji-Hoon Park, Sou Hyun Lee, Ji Seob Kim.
Writing – original draft: Ji-Hoon Park.
Writing – review & editing: Ji-Hoon Park, Hyo-Jin Lee, Ji Seob Kim.

References

[1] Honeybourne D. Endotracheal cuff pressure and tracheal mucosal blood flow: endoscopic study of effects of four large volume cuffs. Br Med J (Clin Res Ed) 1984;288:1237.
[2] Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. Am J Respir Crit Care Med 2005;171:388–416.
[3] Lorente L, Blot S, Rello J. Evidence on measures for the prevention of ventilator-associated pneumonia. Eur Respir J 2007;30:1193–207.
[4] Liu J, Zhang X, Gong W, et al. Correlations between controlled endotracheal tube cuff pressure and postprocedural complications: a multicenter study. Anesth Analg 2010;111:1133–7.
[5] Dobrin P, Canfield T. Cuffed endotracheal tubes: mucosal pressures and tracheal wall blood flow. Am J Surg 1977;133:562–8.
[6] Conrardy PA, Goodman LR, Lainge F, et al. Alteration of endotracheal tube position. Flexion and extension of the neck. Crit Care Med 1976;4:8–12.
[7] Goodman LR, Conrardy PA, Laing F, et al. Radiographic evaluation of endotracheal tube position. AJR Am J Roentgenol 1976;127:433–4.
[8] Bernhard WN, Yost L, Joynes D, et al. Intracuff pressures in endotracheal and tracheostomy tubes. Related cuff physical characteristics. Chest 1985;87:720–5.
[9] Guyton D, Banner MJ, Kirby RR. High-volume, low-pressure cuffs. Are they always low pressure? Chest 1991;100:1076–81.
[10] 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.
[11] Lichtenthal PL, Borg UB. Endotracheal cuff pressure: role of tracheal size and cuff volume. Crit Care 2011;15:147–147.
[12] Tsuboi S, Miyashita T, Yamaguchi Y, et al. The TaperGuard endotracheal tube intracuff pressure increase is less than that of the Hi-Lo tube during nitrous oxide exposure: a model trachea study. Anesth Analg 2013;116:609–12.
[13] 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.
[14] Rosato L, Avenia N, Bernante P, et al. Complications of thyroid surgery: analysis of a multicentric study on 14,934 patients operated on in Italy over 5 years. World J Surg 2004;28:271–6.
[15] Lichtenthal PR, Maul D, Borg U. Do tracheal tubes prevent microaspiration? Br J Anaesth 2011;107:821–2.
[16] Kim HC, Lee YH, Kim E, et al. Comparison of the endotracheal tube cuff pressure between a tapered- versus a cylindrical-shaped cuff after changing from the supine to the lateral flank position. Can J Anaesth 2015;62:1063–70.
[17] Choi E, Park Y, Jeon Y. Comparison of the cuff pressure of a TaperGuard endotracheal tube and a cylindrical endotracheal tube after lateral rotation of head during middle ear surgery: a single-blind, randomized clinical consort study. Medicine (Baltimore) 2017;96:e6257.
[18] Weiss M, Gerber AC, Dullenkopf A. Appropriate placement of intubation depth marks in a new cuffed paediatric tracheal tube. Br J Anaesth 2005;94:80–7.
[19] Kim JT, Kim HJ, Ahn W, et al. Head rotation, flexion, and extension alter endotracheal tube position in adults and children. Can J Anaesth 2009;56:751–6.
[20] Minonishi T, Kinoshita H, Hirayama M, et al. The supine-to-prone position change induces modification of endotracheal tube cuff pressure accompanied by tube displacement. J Clin Anesth 2013;25:28–31.
[21] 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.
[22] Brown BM, Oshita AK, Castellino RA. CT assessment of the adult extrathoracic trachea. J Comput Assist Tomogr 1983;7:415–8.

[23] Vock P, Spiegel T, Fram EK, et al. CT assessment of the adult intrathoracic cross section of the trachea. J Comput Assist Tomogr 1984;8:1076–82.
[24] Abramson ZR, Susarla S, Tagoni JR, et al. Three-dimensional computed tomographic analysis of airway anatomy. J Oral Maxillofac Surg 2010;68:363–71.
[25] Otoch JP, Minamoto H, Perini M, Carneiro FO, de Almeida Artifon EL. Is there a correlation between right bronchus length and diameter with age? J Thorac Dis 2013;5:306–9.
[26] Shiotsuka J, Lefor AT, Sanui M, Nagata O, Horiguchi A, Sasabuchi Y. A quantitative evaluation of fluid leakage around a polyvinyl chloride tapered endotracheal tube cuff using an in-vitro model. HSR Proc Intensive Care Cardiovasc Anesth 2012;4:169–75.
[27] Li Bassi G, Ranzani OT, Marti JD, et al. An in vitro study to assess determinant features associated with fluid sealing in the design of endotracheal tube cuffs and exerted tracheal pressures. Crit Care Med 2013;41:518–26.
[28] Chang JE, Kim H, Han SH, et al. Effect of endotracheal tube cuff shape on postoperative sore throat after endotracheal intubation. Anesth Analg 2017;125:1240–5.
[29] Safdar N, Crnich CJ, Maki DG. The pathogenesis of ventilator-associated pneumonia: its relevance to developing effective strategies for prevention. Respir Care 2005;50:725–39. discussion 739-741.
[30] Christensen AM, Willemoes-Larsen H, Lundby L, Jakobsen KB. Postoperative throat complaints after tracheal intubation. Br J Anaesth 1994;73:786–7.
[31] Jung TH, Rho JH, Hwang JH, Lee JH, Cha SC, Woo SC. The effect of the humidifier on sore throat and cough after thyroidectomy. Korean J Anesthesiol 2011;61:470–4.
[32] Hisham AN, Roshilla H, Amri N, et al. Post-thyroidectomy sore throat following endotracheal intubation. ANZ J Surg 2001;71:669–71.
[33] Prasanna Kumar S, Ravikumar A. Biometric study of the internal dimensions of subglottis and upper trachea in adult Indian population. Indian J Otolaryngol Head Neck Surg 2014;66:261–6.