

The Effect of Esophageal Stethoscope Insertion on the Cuff Pressure: a Prospective Observational Study

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Abstract

Background: High cuff pressure can induce ischemic injury to the trachea. An esophageal stethoscope can increase the cuff pressure. The purpose of this study was to evaluate the effect of an esophageal stethoscope insertion on the cuff pressure.

Methods: Patients, who were scheduled for surgeries under general anesthesia, were enrolled in this prospective observational study. After induction of anesthesia, an anesthesiologist intubated a tracheal tube into the patient's trachea and inflated the cuff manually. Then, an investigator checked the initial cuff pressure using a manometer. Next, the cuff pressure was adjusted to 24-26 mmHg. The cuff pressure was rechecked after insertion of an esophageal stethoscope. We recorded the change in cuff pressure by esophageal stethoscope.

Results: One hundred twelve patients completed this study. The cuff pressure increased by an esophageal stethoscope in almost all patients and the mean cuff pressure change was 3.0 ± 3.4 cmH₂O in all patients. Among all subjects, cuff pressure change over 5 cmH₂O was recorded in 24 patients. When we compared the patient characteristics between patients whose cuff pressure changed over 5 cmH₂O with that of other patients, females were more affected by insertion of an esophageal stethoscope, in terms of cuff pressure increase.

Conclusion: Esophageal stethoscope insertion could increase cuff pressure, and females are more affected by it. Therefore, anesthesiologists should check the cuff pressure with a manometer after insertion of an esophageal stethoscope and readjust the pressure appropriately.

Trial registration: ClinicalTrials.gov Identifier NCT03375554, registered on 12 December 2017 (<https://register.clinicaltrials.gov/prs/app/action/SelectProtocol?sid=S0007N0H&selectaction=Edit&uid=U00026JX&ts=2&cx=-ivu5vz>)

Background

For general anesthesia, tracheal intubation is necessary in most cases. Just after insertion of a tracheal tube into the trachea, clinicians inflate the tracheal cuff with air to prevent pulmonary aspiration and air leakage during positive pressure mechanical ventilation. If the tracheal cuff pressure is over 30 cmH₂O, it could impair the microcirculation of capillary bed of the tracheal mucosa. This can cause severe complications, such as tracheal stenosis or rupture as well as postoperative sore throat [1–5].

Body temperature monitoring during anesthesia is essential for patient safety. Usually, low body temperature is a common problem during the intraoperative period. Low body temperature is associated with late recovery from anesthesia, coagulation abnormalities, and immune dysfunction. Therefore, the committee on standards and practice parameters (CSPP) of the American Society of Anesthesiologists (ASA) recommends that body temperature should be monitored as a standard for basic anesthesia monitoring. Core temperature can be obtained from the esophagus, nasal cavity, bladder, tympanic

membrane, pulmonary artery, and rectum [6, 7]. Esophageal stethoscopes was first used for auscultation of heart and lung sounds [8]. Currently, it seems to be mainly used for core temperature monitoring because many manufacturers make the esophageal stethoscope with the insertion of a temperature sensor into it. The esophagus and trachea run conterminously in parallel from the larynx downward in the human body. The trachea positions anteriorly to the esophagus. The esophagus is composed of mucosa, muscle, and connective tissue. The trachea is also composed of smooth muscle and contains multiple cartilage rings. However, the cartilage rings are not a complete circular ring; they have a missing portion on the posterior side. Therefore, the posterior wall of the trachea and the anterior wall of the esophagus are close together; that is, the two walls may influence the other. A previous study showed that insertion of the probe of transesophageal echocardiography (TEE) increased the cuff pressure in patients who received open heart surgeries. The purpose of this study was to evaluate the effect of esophageal stethoscope insertion on cuff pressure and to investigate which patient characteristics affect cuff pressure changes.

Methods

This prospective observational study was approved by the institutional review board of the Seoul Metropolitan Government Seoul National University Boramae Medical Center (16-2017-78), and written informed consent was obtained from all subjects. The trial was registered prior to patient enrolment at ClinicalTrials.gov (NCT03375554). Adult patients (≥ 18 years old) requiring tracheal intubation for elective surgeries were recruited between April 2018 and June 2018. Patients requiring insertion of a Levin tube or a TEE probe were excluded from this study. Patients who could not use an esophageal stethoscope for body temperature monitoring because of surgical site, such as the oral cavity were also excluded.

After enrolment, we recorded the patient characteristics, including sex, age, height, weight, and body mass index (BMI). We measured tracheal diameter at the level of the suprasternal notch on the preoperative chest X-ray, neck circumference (NC) at the cricoid cartilage level, and thyro-sternal distance (TS) which was from the upper margin of the thyroid cartilage to the suprasternal notch. We calculated the NC/TS ratio because we thought it might affect the cuff pressure change when a stethoscope was inserted into the esophagus after tracheal intubation.

Patients were admitted to the operating theatre without any premedication. Patients were positioned on the operating table with a standard pillow under their head. Pulse oximetry, electrocardiography, and noninvasive arterial blood pressure were monitored in a standard manner. Anesthesia was induced with intravenous administration of lidocaine (30 mg), propofol (1.5 mg/kg), and fentanyl (100 μ g). After loss of consciousness, the patients' lungs were manually ventilated with oxygen and sevoflurane. Next, muscle relaxation was achieved with rocuronium (0.6 mg/kg) for tracheal intubation. An anesthesiologist intubated a tracheal tube (Hi-Lo; Mallinckrodt Medical, Athlone, Ireland) into the patient's trachea with internal diameter of 7.0 mm for women and 7.5 mm for men and inflated the cuff manually. Then, mechanical ventilation was initiated with a volume-controlled mode of 8 ml/kg and inspiratory/expiratory

ratio of 1:2. The respiratory rate was adjusted to maintain an end-tidal carbon dioxide of 35–40 mmHg. The inspiratory oxygen fraction was set to 0.4. Positive end-expiratory pressure was applied to 5 cmH₂O. We did not use nitrous oxide in the trial, as it is not a routine manner at our institute. An investigator checked the initial cuff pressure 3 min after completion of tracheal intubation while blinding the initial cuff pressure to the intubation practitioner. Next, the investigator adjusted the cuff pressure to 24–26 cmH₂O at the point of end-inspiratory pause during mechanical ventilation by a cuff manometer (VBM cuff pressure gauges, VBM Medizintechnik GmbH, Germany). Additionally, the investigator rechecked the cuff pressure 3 min after insertion of an 18 Fr. esophageal stethoscope (Monitemp, ACE Medical Co., South Korea). We recorded the change of cuff pressure by esophageal stethoscope insertion. Finally, we readjusted the cuff pressure to 24–26 cmH₂O to prevent tracheal ischaemic injury by the cuff manometer. We considered a cuff pressure increase over 5 cmH₂O as significant because we adjusted the cuff pressure at approximately 25 cmH₂O, which is considered the mean value of the recommended cuff pressure (20–30 cmH₂O) in some previous guidelines [9–12], before esophageal stethoscope insertion. Anesthesia and surgery were performed as routine practices at our institute.

Statistical Analysis

In a recent study, Kim et al. investigated the cuff pressure change induced by insertion of a TEE probe. In the study, the authors investigated cuff pressure increase due to insertion of a TEE probe. For 22 patients whose trachea was intubated with a single lumen tracheal tube, cuff pressure was increased by approximately 6 cmH₂O [13]. In the study, the authors investigated 5 possible factors that were suspected to affect cuff pressure except tube type. Another previous study presented that tracheal cuff pressure increased by approximately 8.5 cmH₂O when a TEE probe was inserted into the esophagus of patients whose trachea was intubated with a single lumen tracheal tube [14]. The authors of the study investigated the increase of cuff pressure in 38 patients, but they did not evaluate possible risk factors affecting cuff pressure change. We performed this observational and descriptive study to investigate several potential factors which we suspected to affect cuff pressure changes while inserting an esophageal stethoscope. We hoped that the continuous variables that were measured in the trial should be normally distributed. Additionally, we hypothesized there would be difference in cuff pressure change by esophageal stethoscope insertion between sex. As a result, we determined to perform the present study with a sample size of 50 for each sex. We decided to examine 56 patients for each sex, considering a drop-out rate of 10%.

Patient characteristics and outcome measures, including patient age, height, weight, BMI, tracheal diameter, NC, TSD, NC/TSD ratio, initial cuff pressure, and cuff pressure change by esophageal stethoscope insertion are presented as the mean ± standard deviation (SD). Numbers with percentages are presented for the cases of cuff pressure change over 5 cmH₂O by esophageal stethoscope insertion.

Correlation analysis or linear regression was used to evaluate the relationship between potential variables and the initial cuff pressure. Patient characteristics were compared between patients with cuff pressure

change over 5 cmH₂O and those without, using the chi-square test or two sample t-test. In these analyses, the potential variables included sex, age, height, BMI, tracheal diameter, NC, TSD, and NC/TSD ratio. A P < 0.05 was considered significant. Statistical analyses were performed with SPSS Statistics 26.0 software (IBM Corporation, Chicago, IL, USA).

Results

One hundred twelve patients requiring tracheal intubation for general anesthesia were enrolled in the study and completed the study. The demographic data of all patients are presented in Table 1. There was no harm or adverse effects during the trial in all patients.

Table 1
Patient characteristics

Patient characteristics	Female (n = 56)	Male (n = 56)	All (n = 112)
Age (y)	58.4 ± 13.5	58.3 ± 16.0	58.4 ± 14.7
Height (cm)	154.5 ± 5.9	168.8 ± 6.1	161.7 ± 9.4
Weight (kg)	62.0 ± 11.3	71.5 ± 10.1	66.8 ± 11.7
BMI (kg/m ²)	26.0 ± 4.7	25.1 ± 3.1	25.6 ± 4.0
Tracheal diameter	15.6 ± 1.8	18.3 ± 2.2	17.0 ± 2.4
Neck circumference (cm)	35.0 ± 2.6	40.2 ± 2.9	37.6 ± 3.8
TS distance (cm)	7.9 ± 1.3	8.6 ± 1.4	8.2 ± 1.4
NC/TS ratio	4.6 ± 1.1	4.8 ± 1.0	4.7 ± 1.1
BMI; body mass index. Data are presented as the mean ± standard deviation or numbers.			

A total of 16 clinicians from 1st year residents to board-certified anesthesiologists performed tracheal intubation and cuff inflation in the trial (board-certified anesthesiologists: 5, 3rd -4th year residents: 6, 1st -2nd year residents: 5). Table 2 showed the initial cuff pressure, adjusted cuff pressure, and cuff pressure change by esophageal stethoscope insertion. Fifty-eight (51.8%) patients experienced high initial cuff pressure over 30 cmH₂O in the study. Initial cuff pressure was significantly correlated with only sex (p < 0.001) among potential variables (Table 3). After adjustment of cuff pressure to 24–26 cmH₂O by the investigator, cuff pressure was recorded as 24.4 ± 0.7 cmH₂O 3 min after adjustment of cuff pressure in all patients. The cuff pressure was recorded to 27.3 ± 3.6 cmH₂O 3 min after insertion of the stethoscope. The mean cuff pressure change was 3.8 ± 4.0 cmH₂O, 2.2 ± 2.7 cmH₂O, and 3.0 ± 3.4 cmH₂O in females, males, and all patients, respectively (Table 2).

Table 2
Cuff pressure

Patient characteristics	Female (n = 56)	Male (n = 56)	All (n = 112)
Initial cuff pressure (cmH ₂ O)	44.8 ± 26.3	36.8 ± 21.9	37.1 ± 21.9
Adjusted cuff pressure (cmH ₂ O)	24.4 ± 0.7	24.4 ± 0.7	24.4 ± 0.7
Cuff pressure after probe insertion (cmH ₂ O)	28.0 ± 4.1 [22, 40]	26.6 ± 2.9 [22, 40]	27.3 ± 3.6 [22, 40]
Cuff pressure change (cmH ₂ O)	3.8 ± 4.0 [-2, 14]	2.2 ± 2.7 [-2, 14]	3.0 ± 3.4 [-2, 14]
Cuff pressure change > 5 cmH ₂ O (n)	17 (30.4%)	7 (12.5%)	24 (21.4%)
BMI; body mass index. Data are presented as the mean ± standard deviation or numbers.			

Table 3
Correlation coefficient (or regression coefficient) and probability levels between potential variables and initial cuff pressure

Patient characteristics	Correlation coefficient (regression coefficient*)	P
Sex*	-15.893* (-23.510, -8.276)	< 0.001
Age (y)	0.021 (-0.165, 0.206)	0.827
Height (cm)	-0.267 (-0.431, -0.086)	0.004
Weight (kg)	-0.206 (-0.378, -0.022)	0.029
BMI (kg/m ²)	-0.029 (-0.213, 0.158)	0.763
Tracheal diameter	-0.235 (-0.403, -0.051)	0.013
Neck circumference (cm)	-0.292 (-0.453, -0.112)	0.002
TS distance (cm)	-0.073 (-0.255, 0.114)	0.444
NC/TS ratio	-0.077 (-0.259, 0.110)	0.421
*sex was evaluated while male was as reference compared with female using regression analysis. BMI; body mass index.		

Twenty-four patients experienced cuff pressure change over 5 cmH₂O in the trial. For them, the mean cuff pressure change was 8.4 cmH₂O (range 6–14 cmH₂O). Univariable analysis revealed that sex, height, weight, tracheal diameter, and neck circumference were correlated with the initial cuff pressure (Table 3). Multivariable linear regression with stepwise selection showed that only sex was related to the initial cuff pressure (regression coefficient – 15.893 [95% confidence interval: -23.510, -8.276] p < 0.001). Additionally, only sex was related to cuff pressure change over 5 cmH₂O when we compared patient characteristics between patients divided by cuff pressure change > 5 cmH₂O or not (Table 4).

Table 4

Comparison of patients' characteristics between cuff pressure change ≤ 5 cmH₂O vs. cuff pressure change > 5 cmH₂O

Patient characteristics	cuff pressure change ≤ 5	cuff pressure change > 5	P
Sex*			
Female	39 (44.32%)	17 (70.83%)	0.021
Male	49 (55.68%)	7 (29.17%)	
Age (y)	59.25 ± 14.01	55.13 ± 17.08	0.226
Height (cm)	162.30 ± 9.18	159.26 ± 9.78	0.158
Weight (kg)	66.84 ± 11.23	66.50 ± 13.55	0.901
BMI (kg/m ²)	25.36 ± 3.70	26.25 ± 5.00	0.423
Tracheal diameter	17.14 ± 2.42	16.31 ± 2.48	0.145
Neck circumference (cm)	37.90 ± 3.86	36.52 ± 3.34	0.114
TS distance (cm)	8.27 ± 1.38	8.04 ± 1.44	0.472
NC/TS ratio	4.73 ± 1.04	4.71 ± 1.17	0.959
Differences between categorical* and continuous variables were examined by Chi-square test and two sample t-test, respectively.			

Discussion

Esophageal stethoscope insertion into the esophagus increased tracheal cuff pressure under general anesthesia. Cuff pressure change over 5 cmH₂O induced by esophageal stethoscope insertion was observed more in female patients than in male patients.

Several previous studies presented that the TEE probe raised tracheal cuff pressure by 6.3 to 8.5 cmH₂O from the baseline value, while using a single lumen tube for general anesthesia in adult patients [13, 14]. In our study, the mean change in cuff pressure was 3.0 ± 3.4 cmH₂O in 112 patients who received general anesthesia with a single lumen tube. This discrepancy may be due to the diameter difference between the

TEE probe and esophageal stethoscope. However, the esophageal stethoscope is widely used for body temperature monitoring in these days. Therefore, clinicians should be aware of the possibility of cuff pressure change when an esophageal stethoscope is used for body temperature monitoring. Moreover, this knowledge could be helpful in the case of Levin tube insertion for bowel surgeries because 18 Fr. of esophageal stethoscopes and Levin tubes is mostly used in the clinical setting for adult patients. In our study, we used 18 Fr. of esophageal stethoscopes in all patients.

Optimal cuff pressure has been suggested to be between 20 and 30 cmH₂O [9–12]. Routine monitoring of cuff pressure has been emphasized because improper high cuff pressure can cause tracheal injuries [15–17]. To date, however, it seems that cuff pressure monitoring has not been routinely performed in clinical situations, and there is no strong guidance for monitoring cuff pressure [18, 19]. This may be because tracheal injury by high cuff pressure has rarely occurred or has been reported limitedly. In real practice, many clinicians seem to indirectly check cuff pressure by palpating the pilot balloon. Anesthesiologists who performed tracheal intubation and inflation of cuff in this trial were allowed to check the cuff in a routine manner. All of them checked the level of cuff pressure by manual palpation of the pilot balloon. However, this method can cause high cuff pressure because clinicians seem to have a tendency to believe in themselves even though this method cannot estimate exactly cuff pressure [20, 21]. Additionally, it can induce overinflation [10, 15]. In our study, the high initial cuff pressure consisted of these concerns. The initial cuff pressure in our study was different for each clinician. This supports the knowledge from previous studies [10]. Therefore, we believe that there should be a strong guideline for cuff pressure management.

Some previous studies revealed that cuff pressure can be affected by patient position [22] or body temperature [23, 24]. We investigated the effect of esophageal stethoscope insertion only on cuff pressure while performing the trial with the patient's neck in a neutral position. Additionally, we checked the cuff pressure during a short period of tracheal intubation and the initial period of surgical preparation. For that time period, the body temperature of the patient should rarely change. Additionally, we did not use nitrous oxide in the trial. We evaluated the correlation between an increase in cuff pressure and patient characteristics. One of the previous studies did not evaluate the patient risk factors for significant cuff pressure change induced by the insertion of medical instruments [14]. One previous study showed that patient sex, height, weight and anteroposterior/transverse tracheal diameter were not associated with cuff pressure increase. However, the study was performed with a total of 44 patients with unpaired sex ratios (32 males and 10 females), and a single lumen tube was used for only 22 patients (19 males and 3 females) [13]. One previous study investigated whether the cuff pressure increase by a TEE probe varied across 4 age groups in pediatric patients [25]. However, the authors in the study presented no relationship between cuff pressure increase and age. We found that sex was related to cuff pressure change over 5 cmH₂O when we investigated the relationship between potential risk factors and significant cuff pressure change induced by esophageal stethoscope insertion, which may be because the cuff pressure of the smaller tube within the smaller trachea could easily increase by air-inflation. However, this should confirm with additional studies with a large sample size.

There were several limitations in the study. First, we did not evaluate the effect of the esophageal stethoscope on the cuff pressure for the whole operation time. Patient body temperature might change during the ongoing operation, and patient position would be different for various types of surgeries. These factors combined with the esophageal stethoscope would not be easy to evaluate. Additionally, we believe that the esophageal stethoscope should increase the cuff pressure, in addition to these factors. Therefore, we decided to evaluate the effect of esophageal stethoscope insertion alone on cuff pressure, excluding other factors.

In conclusion, esophageal stethoscope insertion for body temperature monitoring during general anesthesia could cause an increase of cuff pressure, especially in female patients. Therefore, anesthesiologists should pay special attention to the effect of esophageal stethoscope insertion on cuff pressure and manage cuff pressure more meticulously.

Abbreviations

Body mass index: BMI; neck circumference: NC; transesophageal echocardiography: TEE; thyro-sternal distance: TS

Declarations

Ethics approval and consent to participate

This study was approved by the institutional review board of Seoul Metropolitan Government Seoul National University Boramae Medical Center (16-2017-78). All participants provided written informed consent prior to the initiation of the study.

Consent for publication

Not applicable. No individual patient data will be reported.

Availability of data and materials

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

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

JEC acquisition of data, analysis and interpretation of data, and drafting the manuscript. JML conception and design of study, acquisition of data, analysis and interpretation of data, drafting the manuscript, and supervision of the study. JL design of study, interpretation of data and drafting the manuscript. JYH acquisition of data and interpretation of data. TTK acquisition of data and interpretation of data. HK acquisition of data and interpretation of data. DW acquisition of data and interpretation of data. YO acquisition of data and interpretation of data. SWM acquisition of data and interpretation of data. All authors read and approved the final manuscript.

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