Research Article

Youngsuk Kwon, Ji Su Jang, Sung Mi Hwang*, Jae Jun Lee*, Seok Jun Hong, Sung Jun Hong, Byung Yong Kang, Ho Seok Lee

The change of endotracheal tube cuff pressure during laparoscopic surgery

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Abstract: Background. We evaluated the endotracheal tube cuff pressure (P_{cuff}) changes during pneumoperitoneum for laparoscopic cholecystectomy and the correlations between body mass index (BMI), pneumoperitoneum time, and P_{cuff} changes.

Methods: Total 60 patients undergoing laparoscopic cholecystectomy were allocated to either a study group (BMI ≥ 25 kg/m^2) or a control group (BMI < 25 kg/m^2). The endotracheal intubation was performed with a high-volume low-pressure cuffed oral endotracheal tube. A manometer was connected to the pilot balloon using a 3-way stopcock and the cuff was inflated. The change in P_{cuff} was defined as the difference between the pressure just before intra-abdominal CO_2 insufflation and the pressure before CO_2 desufflation.

Results: P_{cuff} increased to 5.3 ± 3.6 cmH_2O in the study group and 5.7 ± 5.4 cmH_2O in the control group. There was no significant difference between two groups. While BMI was not correlated with change in P_{cuff} (r = 0.022, p = 0.867), there was a significant correlation between change in P_{cuff} and the duration of pneumoperitoneum (r = 0.309, p = 0.016).

Conclusion: The change in P_{cuff} was not affected by BMI and was significantly correlated with pneumoperitoneum time. We recommend regular measurement and adjustment of P_{cuff} during laparoscopic surgery.

Keywords: Endotracheal tube cuff pressure, Pneumoperitoneum, Body mass index, CO_2 insufflation

***Corresponding author: Sung Mi Hwang,** Department of Anesthesiology and Pain medicine, Hallym University School of Medicine, Chuncheon Sacred Heart Hospital, 77 Sakju-ro, Chuncheon, 24253, South Korea, Tel: +82-10-5361-7702, Fax: +82-33-251-0941, E-mail: h70sm@hallym.or.kr
Jae Jun Lee, Department of Anesthesiology and Pain medicine, Hallym University School of Medicine, Chuncheon Sacred Heart Hospital, 77 Sakju-ro, Chuncheon, 24253, South Korea, Tel: +82-10-3102-8171 Fax: +82-33-251-0941, E-mail: iloveu59@hallym.or.kr
Youngsuk Kwon, Ji Su Jang, Ho Seok Lee, Department of Anesthesiology and Pain medicine, Hallym University School of Medicine, Chuncheon, South Korea
Seok Jun Hong, Sung Jun Hong, Byung Yong Kang, Department of Anesthesiology and Pain medicine, Kangdong Sacred Heart Hospital, Seoul, South Korea
Sung Mi Hwang and Jae Jun Lee equally contributed as the corresponding author

1 Introduction

Pneumoperitoneum via CO_2 insufflation is essential for laparoscopic surgery. Abdominal insufflation markedly increases respiratory system resistance, which returns to baseline immediately after abdominal deflation [1]. However, increased endotracheal tube cuff pressure (P_{cuff}) resulting from pneumoperitoneum may raise the risk of postoperative complications such as cough, sore throat, hoarseness, and blood-streaked expectorations [2, 3]. Several factors affect endotracheal tube P_{cuff} during general anesthesia, including the use of nitrous oxide, changes in head and neck position, pneumoperitoneum, and the Trendelenburg position [1, 2, 4-6]. The current study evaluated endotracheal tube P_{cuff} changes and airway pressure (P_{airway}) changes during pneumoperitoneum for laparoscopic cholecystectomy in the "head up" position. Then, correlations between body mass index (BMI), pneumoperitoneum time, and P_{cuff} changes were investigated.

2 Patients and methods

2.1 Patient selection

The current study was approved by the relevant institutional review board and written informed consent was obtained from all patients. The patients included ranged from 20–70 years in age, were of American Society of Anesthesiologists physical status I and II, and were undergoing elective one-port laparoscopic cholecystectomy. Patients with a history of tracheostomy, abnormal airway anatomy, lung disease with impaired compliance, upper respiratory tract infection within the last 2 weeks and failure of first intubation, and bucking after intubation or during surgery were excluded. The protocol of this clinical trial was registered at the Clinical Information Service (available at http://cris.nih.go.kr, KCT 0002937). Patients were allocated to either a study group (BMI ≥ 25 kg/m^2) or a control group (BMI < 25 kg/m^2).

2.2 Anesthesia and endotracheal tube cuff pressure measurement

No premedication was given to any patients included in the study. On arrival to the operating room, standard monitoring with electrocardiography, pulse oximetry, noninvasive blood pressure, and bispectral index (BIS) was performed. Anesthesia was induced via propofol (1.5–2.0 mg/kg) and rocuronium (6–8 mg/kg). Endotracheal intubation was performed with a high-volume low-pressure cuffed oral endotracheal tube of appropriate size (male 7.5 mm ID and Female 7 mm ID) by an experienced anesthesiologist. After tracheal intubation, a manometer (Mallinckrodt pressure manometer; Mallinckrodt Covidien, Athlone, Ireland) was connected to the pilot balloon using a 3-way stopcock and the endotracheal tube cuff was inflated with air using a 10 mL syringe. The target pressure was 22 cmH_2O. Air leakage around the endotracheal tube was monitored with a stethoscope. All measurements were taken during the inspiratory phase of positive pressure ventilation and performed by one anesthesiologist. Mechanical ventilation was controlled to maintain the end tidal carbon dioxide tension at 35 to 40 mmHg. Anesthesia was maintained using 50% oxygen in nitrous oxide mixture and desflurane. The inhalational desflurane concentration was adjusted to maintain systolic blood pressure within ± 20% of the pre-anesthetic value and maintain the BIS at 40–60. Body temperature (36–37°C) was maintained by forced air warming and controlled room temperature. All patients received abdominal CO_2 insufflation with intra-abdominal pressure maintained at 12 mmHg prior to adopting a head-up position. P_{cuff} was monitored continuously until CO_2 desufflation, and the change in P_{cuff} was defined as the difference between the pressure just before intra-abdominal CO_2 insufflation and the pressure before CO_2 desufflation. Airway pressure (P_{airway}) was also monitored, and change in P_{airway} was defined in the same manner. Body temperature was checked during surgery and pneumoperitoneum time was recorded. Sore throat was assessed at 1 and 24 hours after extubation. The grade of sore throat was evaluated using a numerical rating scale ranging from 0 (no discomfort) to 10 (most severe discomfort).

2.3 Statistical analysis

The sample size was calculated using power analysis (α = 0.05, power = 0.9) based on a previous study [2]. Twenty-five patients were required in each group (N = 50), and a total of sixty patients were recruited to allow for an estimated dropout rate of 10%. SPSS v. 24.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. Data are expressed as numbers or mean ± SD. The independent *t*-test was used for comparisons of age, height, weight, BMI, duration of anesthesia and surgery, changes in P_{cuff} and P_{airway}, and sore throat grade between the two groups at each time-point. Pearson's correlations were calculated to assess relationships between change in P_{cuff} and BMI and pneumoperitoneum time for all patients. $P < 0.05$ was deemed to indicate statistical significance.

3 Results

3.1 Demographic data

A total of 66 patients undergoing one-port laparoscopic cholecystectomy under general anesthesia were assessed for eligibility. Two declined to participate, thus a total of 64 patients were enrolled: 33 in the study group and 31 in the control group. One patient in each group was excluded due to bucking after intubation, and the surgery method was changed to open cholecystectomy in one patient in the study group. One patient in the study group was excluded due to hypothermia. Therefore, 30 patients in each group were included in the final analysis (Figure 1). Demographic and clinical characteristics of the patients are shown in Table 1. By virtue of the study design (*i.e.*, the

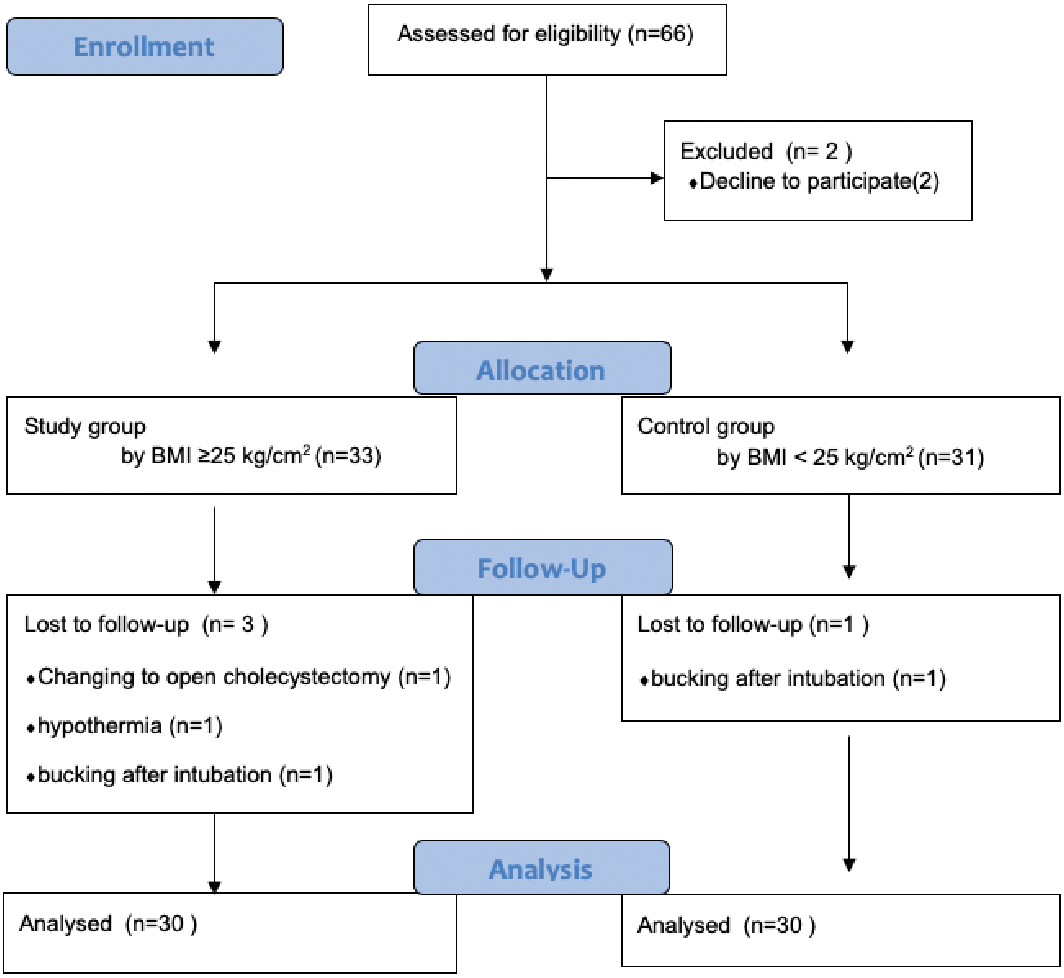

Figure 1: Flow chart of patients analyzed

group allocation criterion), BMI and body weight differed significantly in the two groups.

3.2 Changes of P_{cuff} and P_{airway}

P_{cuff} increased to 5.3 ± 3.6 cmH_2O in the study group and 5.7 ± 5.4 cmH_2O in the control group from just before CO_2 insufflation to prior desufflation. However, there was no significant difference between the two groups (Table 2). After CO_2 desufflation, P_{cuff} decreased or remained stable in all but one patient in each group. The mean changes were 1.7 ± 1.9 cmH_2O in the study group and 1.4 ± 1.6 cmH_2O in the control group. Changes in P_{airway} were similar to changes in P_{cuff}, and there was no significant difference between the two groups (Table 2). After CO_2 desufflation, P_{airway} either decreased or remained stable in all patients. The mean changes were 3.0 ± 2.0 cmH_2O in the study group and 2.9 ± 1.8 cmH_2O in the control group.

3.3 The correlation between body mass index, pneumoperitoneum time, and P_{cuff} changes

There was a significant correlation between the change in P_{cuff} and the duration of pneumoperitoneum ($r = 0.309$, $p = 0.016$) (Figure 2). BMI was not correlated with the change in P_{cuff} ($r = 0.022$, $p = 0.867$) (Figure 3). Sore throat score at 1 and 24 hours after extubation did not differ significantly between the two groups.

4 Discussion

Based on international guidelines, P_{cuff} should be kept between 20 and 30 cm H_2O using a manometer [7]. The pressure within the inflated cuff is dynamic and can be altered by various clinical factors including the size and shape of the trachea, the use of N_2O, head or neck posi-

Table 1: Patient demographics and clinical characteristics.

	Study group (n=30)	Control group (n=30)
Age (yrs)	46 ± 13.6	48.5 ± 10.1
Male/female	9/21	10/20
Height (cm)	160.8 ± 9.3	162.6 ± 7.0
Weight (kg)	73.1 ± 10.0*	58.2 ± 8.3
BMI (kg/m²)	28.2 ± 2.2*	21.9 ± 1.9
Duration of anesthesia (min)	64.5 ± 11.5	59.2 ± 12.6
Duration of surgery (min)	50.2 ± 10.9	45.0 ± 10.7
Pneumoperitoneum time (min)	26.2 ± 8.5	25.4 ± 9.0

Values are expressed as the mean ± SD or number of patients. The BMI of each group was ≥ 25 kg/m2 in the study group and < 25 kg/m² in the control group. BMI: body mass index. *p < 0.001

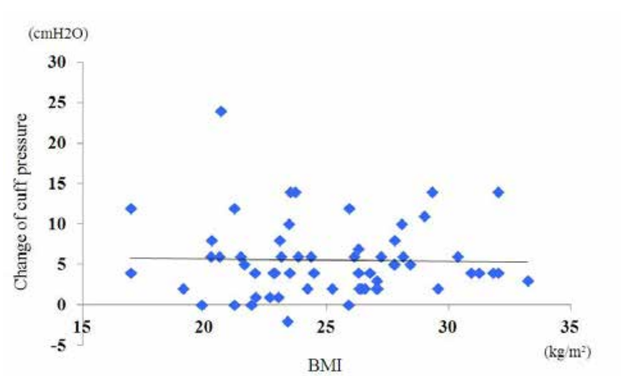

Figure 2. The relationship between the change in P_{cuff} and BMI. There is no significant correlation between the change in P_{cuff} and BMI (r = 0.022, p = 0.867). P_{cuff}: endotracheal tube cuff pressure, BMI: body mass index.

tion, body temperature, the use of specialized surgical instruments [1, 2, 4-6, 8], endotracheal suctioning, and coughing [9]. However, no standard exists with regard to the frequency and method of P_{cuff} monitoring, and P_{cuff} measurement is not part of routine anesthesia monitoring. While inappropriately low P_{cuff} can induce ventilator leakage during mechanical ventilation and aspiration, excessive P_{cuff} can increase the risk of postoperative complications such as cough, sore throat, hoarseness, and

Table 2: Comparison of pressure change and sore throat grade between groups

	Study group (n=30)	Control group (n=30)	p-value
P_{airway} (cm H_2O)	4.7 ± 1.7	4.2 ± 2.2	0.281
P_{cuff} (cm H_2O)	5.3 ± 3.6	5.7 ± 5.4	0.718
NRS of sore throat T_1	2.6 ± 1.9	1.9 ± 1.7	0.119
NRS of sore throat T_{24}	0.6 ± 0.6	0.5 ± 0.7	0.597

Values are expressed as the mean ± SD. The BMI of each group was ≥ 25 kg/m² in the study group and < 25 kg/m² in the control group. P_{airway}: change of airway pressure, P_{cuff}: change of endotracheal tube cuff pressure. NRS: numeric rating scale, $T_{1,\ 24}$: at 1, 24 hour after extubation. BMI: body mass index.

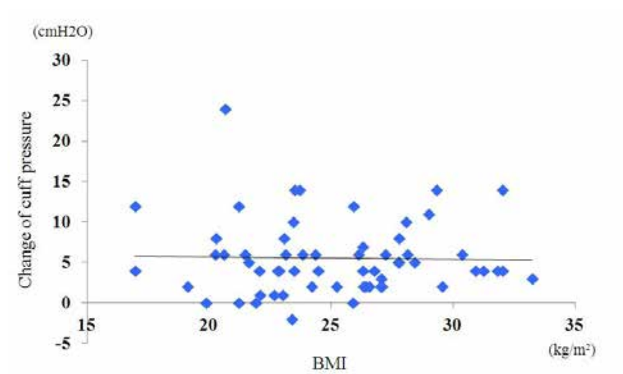

Figure 3. Relationship between the change in P_{cuff} and pneumoperitoneum time.

There is weak correlation between the change in P_{cuff} and pneumoperitoneum time (r = 0.309, p = 0.016).

blood-streaked expectorations [2, 3]. The impairment of tracheal mucosal blood flow is also an important factor in tracheal morbidity associated with intubation. Hence, it is recommended that cuff inflation pressure should not exceed 30 cmH_2O [10].

The frequency of laparoscopic surgery is increasing. Pneumoperitoneum for laparoscopic surgery is essential and causes increased respiratory system resistance. However, respiratory system resistance reportedly returns to baseline immediately after abdominal deflation [1]. The concern of the anesthesiologist is the change in P_{cuff} caused by pneumoperitoneum for surgery. Yildirim et al. reported that pneumoperitoneum by CO_2 insufflation and the reverse Trendelenburg position caused P_{cuff} elevation and a higher incidence of sore throat after surgery [11]. Yu et al. reported that a head-up position did not affect P_{cuff} [2]. However, they investigated P_{cuff} during a short period just before and after abdominal insufflation and position change in laparoscopic surgery. Geng et al. observed increases in P_{cuff} and P_{airway} during pneumoperitoneum and with patients in the Trendelenburg position [6]. They suggested that the increased P_{airway} during laparoscopic surgery would conduct and press part of the cuff, resulting in increased P_{cuff}. In the current study, the effect of the head-up position was difficult to assess because CO_2 insufflation and the head-up position change were performed almost simultaneously. Gali et al. reported that peak inspiratory P_{airway} at 30 minutes after incision for robotically assisted hysterectomy with pneumoperitoneum and the steep Trendelenburg position increased in conjunction with increasing BMI [12]. In the current study, which involved pneumoperitoneum and the head-up position, P_{cuff} and P_{airway} were monitored continuously until abdominal CO_2 desufflation. P_{cuff} and P_{airway} were gradually increased during pneumoperitoneum regardless of BMI. Sore throat is a common postoperative complaint following endotracheal intubation [13]. It has been suggested that over-inflation may increase the cuff-tracheal contact area and damage the tracheal mucosa [14]. In the present study, there was no difference in sore throat between the two groups, and sore throat scores were lower than expected. P_{cuff} was very high when inflated by the anesthesiologist, according to his personal experience using the pilot balloon palpation method without the assistance of instrumentation. Liu et al. also reported that P_{cuff} estimated by palpation based on personal experience is often much higher than that measured, or what may be optimal [3]. If a surgery is performed under an already high P_{cuff} and the pressure increases during pneumoperitoneum, there will be a greater risk of complications after a surgery. The lower than expected sore throat scores in this study were a result of initial adequate air inflation in accordance with manometer targeting of 22 cmH_2O, and relatively short surgery time. It has been suggested that P_{cuff} should be measured regularly. Kako et al. suggested that fluctuations in P_{cuff} can be expected during prolonged surgical procedures and supports the need for continuous monitoring of P_{cuff} [5].

In the present study, the highest P_{cuff} was 48 cmH_2O. Seven patients in the study group and eight in the control group had P_{cuff} that was > 30 cmH_2O. However, there was no significant relationship between peak P_{cuff} and sore throat score. If the surgery time is extended and P_{cuff} is not monitored, an increase in intracuff pressure may compromise perfusion to the tracheal mucosa and cause patient discomfort [10]. Nitrous-oxide anesthesia during laparoscopy also increases the cuff pressure and the incidence of postoperative sore throat. Thus, routine monitoring of cuff pressure is needed. [15]

P_{cuff} can also be reduced by several factors [8, 13]. In the supine position, during the induction of anesthesia, the loss of consciousness is associated with loss of the tonicity of the muscles around the neck. This may cause an initial decrease in P_{cuff}, and the continuous unconsciousness and paralysis over time may result in further reduction in P_{cuff} [16]. In one study, P_{cuff} values were < 20 cmH_2O in 30% of patients in intensive care unit, and patients who were less sedated with higher levels of consciousness had greater fluctuations in P_{cuff} [8]. In the current study there were also initial decreases in P_{cuff} in five patients in the study group and six in the control group. However, there were no audible leakages. Because the change in P_{cuff} was defined as the difference in P_{cuff} between the pressure just prior intra-abdominal CO_2 insufflation and the pressure before CO_2 desufflation, initial P_{cuff} decreases did not affect the results.

The present study had some limitations. First, the mean BMI in the study group was lower than expected, although by design, there was a statistically significant difference in BMI between the two groups. Second, pneumoperitoneum time was relatively short. If BMI had differed more substantially in the two groups, and pneumoperitoneum time had been longer, different results may have been obtained.

5 Conclusion

The change in P_{cuff} was not affected by BMI, and it was significantly correlated with pneumoperitoneum time in laparoscopic cholecystectomy. Thus, we recommend regular measurement and adjustment of P_{cuff} in all patients during laparoscopic surgery with nitrous–oxide anesthesia.

Conflict of interest statement: Authors state no conflict of interest.

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