Research Article

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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 $\geq$ 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 $5.3 \pm 3.6$ cmH$_2$O in the study group and $5.7 \pm 5.4$ cmH$_2$O in the control group. There was no significant difference between the 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 pneumoperitoneum time ($r = 0.309, p = 0.016$).

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

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/m²) or a control group (BMI < 25 kg/m²).

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 cmH₂O. 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 CO₂ insufflation with intra-abdominal pressure maintained at 12 mmHg prior to adopting a head-up position. \( P_{\text{cuff}} \) was monitored continuously until CO₂ desufflation, and the change in \( P_{\text{cuff}} \) was defined as the difference between the pressure just before intra-abdominal CO₂ insufflation and the pressure before CO₂ desufflation. Airway pressure (\( P_{\text{airway}} \)) was also monitored, and change in \( P_{\text{airway}} \) 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 (\( \alpha = 0.05 \), 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 \( P_{\text{cuff}} \) and \( P_{\text{airway}} \), and sore throat grade between the two groups at each time-point. Pearson’s correlations were calculated to assess the relationships between change in \( P_{\text{cuff}} \) 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
group allocation criterion), BMI and body weight differed significantly in the two groups.

### 3.2 Changes of $P_{\text{cuff}}$ and $P_{\text{airway}}$

$P_{\text{cuff}}$ increased to 5.3 ± 3.6 cmH$_2$O in the study group and 5.7 ± 5.4 cmH$_2$O 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, $P_{\text{cuff}}$ decreased or remained stable in all but one patient in each group. The mean changes were 1.7 ± 1.9 cmH$_2$O in the study group and 1.4 ± 1.6 cmH$_2$O in the control group. Changes in $P_{\text{airway}}$ were similar to changes in $P_{\text{cuff}}$ and there was no significant difference between the two groups (Table 2). After CO$_2$ desufflation, $P_{\text{airway}}$ either decreased or remained stable in all patients. The mean changes were 3.0 ± 2.0 cmH$_2$O in the study group and 2.9 ± 1.8 cmH$_2$O in the control group.

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

There was a significant correlation between the change in $P_{\text{cuff}}$ and the duration of pneumoperitoneum ($r = 0.309, p = 0.016$) (Figure 2). BMI was not correlated with the change in $P_{\text{cuff}}$ ($r = 0.022, p = 0.867$) (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, $P_{\text{cuff}}$ should be kept between 20 and 30 cm H$_2$O 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$_2$O, head or neck posi-
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 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 cmH2O [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 CO2 insufflation and the reverse Trendelenburg position caused P cuff elevation.

Table 1: Patient demographics and clinical characteristics.

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

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

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

<table>
<thead>
<tr>
<th></th>
<th>Study group (n=30)</th>
<th>Control group (n=30)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAway (cm H₂O)</td>
<td>4.7 ± 1.7</td>
<td>4.2 ± 2.2</td>
<td>0.281</td>
</tr>
<tr>
<td>P cuff (cm H₂O)</td>
<td>5.3 ± 3.6</td>
<td>5.7 ± 5.4</td>
<td>0.718</td>
</tr>
<tr>
<td>NRS of sore throat T₁</td>
<td>2.6 ± 1.9</td>
<td>1.9 ± 1.7</td>
<td>0.119</td>
</tr>
<tr>
<td>NRS of sore throat T₂₄</td>
<td>0.6 ± 0.6</td>
<td>0.5 ± 0.7</td>
<td>0.597</td>
</tr>
</tbody>
</table>

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. PAway: change of airway pressure, P cuff: change of endotracheal tube cuff pressure. NRS: numeric rating scale, T₁, 2₄; at 1, 2₄ hour after extubation. BMI: body mass index.

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.

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).
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 CO₂ 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 CO₂ 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 and position change of instrumentation. Liu et al. also reported that 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 cmH₂O 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 just prior intra-abdominal CO₂ insufflation and the pressure before CO₂ 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.

References

in head-up or head-down position. BMC Anesthesiol. 2014; 14: 75