Effects of different inhaled oxygen concentration and end-expiratory positive pressure on Pa-etCO\textsubscript{2} in patients undergoing gynecological laparoscopic surgery

Guiqi Geng, Jingyi Hu, Shaoqiang Huang

Department of Anesthesiology, Obstetrics and Gynecology Hospital, Fudan University, Shanghai, China

Received September 7, 2013; Accepted October 5, 2013; Epub October 25, 2013; Published October 30, 2013

Abstract: There is some disagreement about whether the PetCO\textsubscript{2} is reliable in predicting the PaCO\textsubscript{2} in laparoscopic procedures with CO\textsubscript{2} inflation. The aim of the present study is to measure the Pa-etCO\textsubscript{2} differences over time in healthy patients undergoing gynecological laparoscopic surgery with different ventilation methods. Methods: After intubation, patients were randomized into three groups. The patients in group A were ventilated with air/O\textsubscript{2} (FiO\textsubscript{2} = 50%) and supplied with PEEP (5cmH\textsubscript{2}O). The patients in group B were ventilated with 50% oxygen while the patients in group C were ventilated with 100% oxygen. All patients were conducted with volume-controlled ventilation. PetCO\textsubscript{2} and PaCO\textsubscript{2} were measured at baseline, one minute after intubation, every 30 min thereafter and 5 minutes after deflation of pneumoperitoneum. Results: The differences in Pa-etCO\textsubscript{2} between groups A, B and C were insignificant one minute after intubation. The Pa-etCO\textsubscript{2} in group B and C significantly increased compared with that in group A at other time points after intubation. Conclusion: Oxygen concentration and positive end-expiratory pressure could affect Pa-etCO\textsubscript{2} in laparoscopic surgery patients.

Keywords: FiO\textsubscript{2}, PEEP, PaCO\textsubscript{2}, PetCO\textsubscript{2}, laparoscopic surgery

Introduction

The relatively good hemodynamic and respiratory tolerance to abdominal CO\textsubscript{2} inflation has mostly been observed in healthy patients during short-lasting laparoscopic procedures. However, long-term laparoscopic surgery requires prolonged CO\textsubscript{2} pneumoperitoneum, which may facilitate CO\textsubscript{2} absorption and its accumulation in blood and tissues, eventually causing hypercapnia.

Anesthetists use end-tidal PCO\textsubscript{2} (PetCO\textsubscript{2}) values routinely to monitor the adequacy of ventilation. However, there is some disagreement about whether the PetCO\textsubscript{2} is reliable in predicting the PaCO\textsubscript{2} (PaCO\textsubscript{2}) in laparoscopic procedures with CO\textsubscript{2} inflation. In some reports, PetCO\textsubscript{2} is accepted as a reliable method of measuring PaCO\textsubscript{2} [1-4] in the absence of cardio-respiratory disease. But in other studies, the Pa-etCO\textsubscript{2} differences increase [5-7].

The clinical utility of PetCO\textsubscript{2} as a surrogate for PaCO\textsubscript{2} depends on the gradient between PaCO\textsubscript{2} and PetCO\textsubscript{2}. This gradient depends primarily on the degree of alveolar dead space. Larson and Severinghaus reported that the administration of O\textsubscript{2} to awake sitting subjects led to an increase in Pa-etCO\textsubscript{2} [8]. As we know, inhaled oxygen concentration and positive end-expiratory pressure (PEEP) affect the volume of alveolar dead space in mechanical ventilation during general anesthesia [9, 10]. We hypothesized that, during pneumoperitoneum, PetCO\textsubscript{2} differs from PaCO\textsubscript{2} and the difference between PaCO\textsubscript{2} and PetCO\textsubscript{2} might be affected by oxygen concentration and PEEP. The aim of the present study is to measure the Pa-etCO\textsubscript{2} differences over time in healthy patients undergoing gynecological laparoscopic surgery with different ventilation methods.

Materials and methods

With approval by the Institutional Ethics Committee and written informed consent, 90 consecutive healthy, ASA physical status I–II, and non-smoking patients undergoing gynecol-
logical laparoscopic surgery were enrolled in the study. The exclusion criteria were signs of cardiopulmonary disease, acute infection and body mass index ≥ 30.

No pre-medication was used before anesthesia induction. Patients were monitored with ECG, pulse oximetry and non-invasive blood pressure measurement and received a pre-operative fluid challenge (Lactated Ringer, 10 ml kg⁻¹). Before anesthesia induction, a radial artery catheter was inserted to collect blood samples.

Anesthesia was induced with sufentanil (0.5 µg kg⁻¹) and propofol (2 mg kg⁻¹), and orotracheal intubation was facilitated by rocuronium (0.6 mg kg⁻¹). Anesthesia was maintained with propofol and remifentanil to obtain stable hemodynamic parameters (i.e., pulse rate and blood pressure variations < 20% of the pre-induction values).

After intubation, patients were randomized into three groups. The patients in group A were ventilated with air/O₂ (FiO₂ = 50%) and supplied with PEEP (5cmH₂O). The patients in group B were ventilated with 50% oxygen. The patients in group C were ventilated with 100% oxygen. All patients under volume-controlled ventilation by means of the Datex-Ohmeda machine (Aestiva/5; Datex-Ohmeda, USA) were adapted to obtain a PetCO₂ value between 4.0 and 5.5 kPa by adjusting minute ventilation up to an airway pressure limit (30cmH₂O). PaCO₂ was measured at baseline (before general anesthesia), one minute after intubation, every 30 min thereafter and 5 minute after deflation of pneumoperitoneum by using the blood gas analyser (i-STAT1, ABBOTT, USA). Heart rate, blood pressure, pulse oximetry, PetCO₂, airway pressure and minute ventilation were recorded at baseline (before general anesthesia), one minute after intubation, every 30 min thereafter and 5 minutes after deflation of pneumoperitoneum. The patient’s body temperature was continuously monitored via nasopharynx and maintained at 36° to 37°C by external heating. The room temperature was maintained at 24° to 26°C.

During anesthesia, hydration was provided with Lactate-Ringer solution, 7.5 ml kg⁻¹ h⁻¹ and modified thereafter to obtain a diuresis ≥ 1 ml kg⁻¹ h⁻¹. Intra-abdominal pressure was steadily maintained between 12 and 14 mmHg by a CO₂ inflator (Karl Storz, Germany). Following CO₂ inflation and till the end of surgery, patients were placed in a fixed 20° Trendelenburg position.

### Statistical analysis

Quantitative data were presented as mean ± SD. Statistical analysis was conducted by using SPSS Version 13.0. A value of \( P < 0.05 \) was considered statistically significant.

---

**Table 1. Comparison of General Information of Three Groups (Mean ± SD)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yr)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Duration of operation (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (n = 30)</td>
<td>37 ± 7</td>
<td>59 ± 8</td>
<td>160 ± 6</td>
<td>122 ± 13</td>
</tr>
<tr>
<td>B (n = 30)</td>
<td>39 ± 8</td>
<td>55 ± 7</td>
<td>158 ± 5</td>
<td>130 ± 16</td>
</tr>
<tr>
<td>C (n = 30)</td>
<td>38 ± 6</td>
<td>56 ± 5</td>
<td>160 ± 4</td>
<td>120 ± 21</td>
</tr>
</tbody>
</table>

---

**Figure 1.** Comparison of Pa-\( et \)CO\(_2\) at Different Time Points Among Three Groups. All values represent the Mean ± SD. *\( P < 0.05 \), **\( P < 0.01 \), compared with Group A at the same time point. ▽\( P < 0.05 \), △\( P < 0.01 \), compared with Group B at the same time point.


Results

All patients enrolled in the study completed the protocol. The three groups did not differ with respect to age, weight, height and duration of operation (Table 1).

Compared with 1 minute after intubation, the difference of Pa-etCO₂ in group B and C obviously increased 30 minute after intubation. Among these groups, there were significant differences in Pa-etCO₂ 60 minutes after intubation and thereafter (Figure 1).

Discussion

The number of laparoscopic gynecological procedures in clinical practice has increased rapidly because of their advantages that include minimal invasiveness, reduced pain, and fast recovery. Accurate evaluation of PaCO₂ is necessary in anesthesia management during the aforementioned surgery to assess ventilation efficacy and to avoid hypercapnia, which may lead to sympathetic excitation, hypertension, tachycardia, and other complications.

PetCO₂ cannot reliably estimate PaCO₂ under these circumstances because CO₂ inflated into the abdominal cavity may cause pulmonary atelectasis, resulting in decreased functional residual capacity and ventilation-perfusion mismatch [11]. Klopfenstein et al. [5] measured PaCO₂ and PetCO₂ simultaneously during laparoscopic colon surgery, with prolonged CO₂ pneumoperitoneum, and concluded that the correlation between PaCO₂ and PetCO₂ was inconsistent after the initiation of CO₂ inflation. Xue et al. [6] found that PetCO₂ was correlated with PaCO₂ only at baseline, before pneumoperitoneum, and underestimated PaCO₂ when CO₂ pneumoperitoneum was established. The results of our study indicate that the differences of Pa-etCO₂ increase with duration of operation extended.

In our study, inhaled 50% oxygen, after anesthesia induction, decreased Pa-etCO₂. We presume that high FiO₂ increases the volume of alveolar dead space and reduces vascular resistance in high perfusion alveolar areas, resulting in the redistribution of blood flow away from low perfusion alveolar areas as proposed by Larson [8]. Thus, the changes in Pa-etO₂ were partially due to the dilution effect of PACO₂ with gas from alveolar dead space.

A hyperoxia-induced reduction in cardiac output may partially explain an increase in Pa-etO₂. Anderson [12] reported that cardiac output decreased by 10.3% when FiO₂ was changed from 0.21 to 1.0. Johann [13] reported that cardiac output decreased by 10.6% after a change in FiO₂ from ≤ 0.6 to 1.0 in patients after coronary artery bypass surgery. The decrease in cardiac output increases Pa-etO₂ by causing the decrease in CO₂ elimination from alveoli and the redistribution of pulmonary blood flow. Although we did not detect any changes in heart rate and arterial pressure during our study, it is likely that a small decrease in cardiac output contributed to the increase in Pa-etCO₂.

Intrapulmonary shunt can lead to the increase in Pa-etO₂ as a consequence of the increase in PaCO₂ with venous admixture. Administration of PEEP reduced the differences of Pa-etCO₂ in our study. Development of atelectasis is a major cause for intrapulmonary shunt during general anesthesia [14]. Dantzker [15] reported that breathing pure O₂ induced absorption atelectasis within 9 min and that pulmonary shunt increased abruptly when FiO₂ increased above 0.8. Brismar [16] found that in chest computed tomography study, atelectasis rapidly developed in the dependent lung regions during the induction of general anesthesia, probably with pure O₂ preoxygenation, but it did not progress with time or increased FiO₂.

There are some limitations in our study. The first is that all patients went through preoxygenation with 100% oxygen, which is a standard clinical practice to ensure patient safety. Nevertheless, preoxygenation with 100% oxygen would result in the development of absorption atelectasis. Although an inflation of the lungs after induction to airway pressure of 3.92 kPa [17] or an application of PEEP of 0.98 kPa [18] can eliminate the atelectasis, we did not perform them. The atelectasis during the induction of anesthesia must have persisted, even if FiO₂ was changed. Secondly, all patients in our study were female.

In conclusion, oxygen concentration and positive end-expiratory pressure could affect Pa-etCO₂ in gynecologic laparoscopic surgery patients. The accuracy of PetCO₂ values as a surrogate for PaCO₂ should be adjusted according to ventilation methods.
Disclosure of conflict of interest

None.

Address correspondence to: Dr. Guiqi Geng, Department of Anesthesiology, Obstetrics and Gynecology Hospital, Fudan University, No.128, Shenyang Road, Shanghai 200090, China. Tel: +86-21-63455050-6868; Fax: +86-21-63455090; E-mail: mzgengguiqi@163.com

References


