Transcutaneous Carbon Dioxide And Oxygen Pressure In Laparoscopic Surgery

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Citation

Abstract
The present study was performed to investigate whether transcutaneous carbon dioxide (CO2) (tcPCO2) and oxygen (tcPO2) pressures are useful in laparoscopic surgery.

TcPCO2, tcPO2, arterial CO2 (PaCO2), and O2 (PaO2) were measured during laparoscopic surgery in 15 patients. Linear regression analysis and the Bland-Altman plot were used to analyze the relation between tcPCO2 and PaCO2, and tcPO2 and PaO2.

Good positive correlation between tcPCO2 and PaCO2 disappeared at 60 min. of inflation. TcPCO2 and PaCO2 had large bias and limit of agreement. TcPO2 and PaO2 had good positive correlation except for 30 min. of inflation. TcPO2 and PaO2 had large bias and limit of agreement.

In Conclusion, TcPCO2 correlated well with PaCO2, but this correlation disappeared during abdominal inflation. TcPCO2 could not be surrogate measurement of PaCO2. TcPO2 correlated well with PaO2 except for early phase of inflation, but could not be a surrogate measurement of PaO2.

INTRODUCTION
For pneumoperitoneum in laparoscopic surgery, carbon dioxide (CO2) is usually used as an inflate gas to decrease pain. CO2 is absorbed into the blood from intraabdominal space by large difference in partial pressures between the pneumoperitoneum and the blood perfusing the peritoneum. This causes hypercarbia and acidosis [1,2]. Therefore, arterial CO2 pressure (PaCO2) is important and should be measured during laparoscopic surgery. However, to measure PaCO2, invasive arterial cannulation or puncture is necessary. End-tidal CO2 pressure (EtCO2) is commonly measured non-invasively during general anesthesia or artificial ventilation, and it is available as a surrogate measurement of PaCO2 in many circumstances. However, in case of ventilation-perfusion mismatch, cardiovascular or respiratory disease, EtCO2 might not be accurate [3,4]. Transcutaneous CO2 pressure (tcPCO2), which is less invasive, is available to predict PaCO2 during general anesthesia for laparotomy when the probe of the device is put on the chest [5].

The present study was performed to investigate whether tcPCO2 and tcPO2 are useful to monitor PaCO2 and PaO2, respectively in laparoscopic surgery.

MATERIALS AND METHODS
After the approval of the ethics committee of the hospital and informed consent from patients, 15 patients aged 40 to 70 years for laparoscopic gastrectomy were enrolled in this study. Those who had respiratory, cardiac, renal, vascular, or liver diseases, and who had taken vasodilator were excluded.

Without any premedication, after insertion of an epidural catheter at T7-8 interspinal space, anesthesia was induced with propofol 2 – 3 mg/kg and fentanyl 3 – 5 µg/kg. Endotracheal intubation was facilitated with vecuronium 0.15 mg/kg. Anesthesia was maintained with intermittent epidural injection of 1.5% mepivacaine 4 – 6 mL, propofol 2-4 mg/kg/min, and 50% nitrous oxide in oxygen. Lactated Ringers solution was infused to keep urine out put more than 0.5 mg/kg/h based on 4 – 8 mL/kg/h. Rectal temperature was monitored.

An arterial catheter was inserted into the left radial artery for blood gas analysis. End-tidal carbon dioxide pressure (EtCO2) was measured with UltimaTM (Datex-Ohmeda, Helsinki, Finland). PaCO2 and PaO2 were
measured with the ABL 625 (Radiometer, Copenhagen, Denmark). TcPCO2 and tcPO2 were measured with TCM4TM (Radiometer, Copenhagen, Denmark). The electrode of the TCM4TM, which was set to 43 degrees Celsius, was placed on the left chest. Abdominal inflation was performed with CO2 at 9-11 mmHg. The parameters were measured before inflation, 30 min and 60 min after start of inflation, and at the end of surgery (after deflation).

Data were shown as mean with the range or number of patients.

Correlations of each parameter were analyzed with linear regression analysis. The Bland-Altman plot was also used to compare the two measurements with the bias (the mean of the differences), and limit of agreement (bias ± 2SD of bias) [6].

**RESULTS**

Patients were 64 (range, 48 – 70) years old, 10 male and 5 female, 161 (150 – 175) cm in height, and 61 (48 – 68) kg in body weight. Duration of surgery was 265 (234 – 345) min. and minimum rectal temperature was 35.8 (34.9 – 37.0) degrees centigrade.

TcPCO2 and PaCO2 had good positive correlation before inflation, at 30 min. of inflation and at the end of surgery, while no correlation was found at 60 min. of inflation (Figure 1). TcPCO2 and PaCO2 had large bias and limit of agreement (Figure 2, Table 1). EtCO2 and PaCO2 had good positive correlation before inflation, but no correlation was seen during inflation and at the end of surgery (Figure 3). EtCO2 and PaCO2 had small bias and limit of agreement before inflation, but they increased during inflation and at the end of surgery (Figure 4, Table 1).

**DISCUSSION**

This study showed that tcPCO2 correlated well with PaCO2, but this correlation disappeared during abdominal inflation and returned after the end of inflation. The Bland-Altman plot showed that tcPCO2 could not be surrogate measurement of PaCO2 all the time. TcPO2 correlated well with PaO2 except for early phase of inflation, but could not be a surrogate measurement of PaO2.

We used TCM4TM to measure tcPCO2 and tcPO2. The electrode was heated to 43 degrees Celsius according to our previous results [7]. In addition, another study showed that during laparotomy, the electrode should be put on the chest to get the best correlation with blood gas analysis [5]. Therefore, we put the electrode on the chest.

In ventilated patients, tcPCO2 was reported to match PaCO2 better than did EtCO2 [8,9]. The present results showed that tcPCO2 had better correlation coefficient (R2 values) with PaCO2 than EtCO2 during and after pneumoperitoneum, while biases were larger with tcPCO2. The correlation between tcPCO2 and PaCO2 decreases as PaCO2 increases, especially over 50 mmHg [10], which might sometimes occur during laparoscopic surgery. Cuvelier et al. [11] also reported that tcPCO2 and tcPO2 were not correlated with PaCO2 and PaO2, respectively, when PaCO2 > 56 mmHg, and PaO2 > 115 mmHg. Our data included PaCO2 over 50 mmHg and PaO2 over 115 mmHg. However, from the graphs of linear regression analysis in our study, the correlations between tcPCO2 and PaCO2 over 50 mmHg, and that between tcPO2 and PaO2 over 115 mmHg seemed to be the same as those under 50 mmHg and 115 mmHg, respectively during laparoscopic surgery. During hyperbaric oxygen in volunteers, tcPO2 correlated well with PaO2 [12]. Therefore, the correlation between tcPO2 and PaO2, and tcPCO2 and PaCO2 might not change according to the increases of PaO2 and PaCO2, respectively.

In the study by Cuvelier et al. [11], tcPO2 overestimated PaO2 and tcPCO2 underestimated PaCO2. However, Bendjelid et al. [13] showed that tcPCO2 overestimated PaCO2. TcPO2 was lower about 10% than PaCO2, and tcPCO2 did not correlate with PaCO2 during hyperbaric oxygen [12]. Our results showed that tcPO2 underestimated PaO2 more than 10% and tcPCO2 overestimated PaCO2 all the time, which are consistent with our previous results during laparotomy [5].

TcPCO2 is more accurate than EtCO2 to predict PaCO2 during laparoscopic gastrectomy and proctectomy with long duration of pneumoperitoneum [14]. TcPCO2 is better measurement of PaCO2 compared with EtCO2 during laparoscopic cholecystectomy [15]. EtCO2 cannot reliably estimate PaCO2 during laparoscopy because CO2 inflated into the abdominal cavity may cause pulmonary atelectasis, resulting in decreased functional residual capacity and ventilation-perfusion mismatch [16]. Our study also showed that tcPCO2 correlated with PaCO2 better than EtCO2 during and after pneumoperitoneum, while large bias and limits of agreement indicated that tcPCO2 could not be a surrogate measurement of PaCO2.
We measured tcPCO2 and PaCO2 at the same time. However, Kuzuta et al. [17] reported that tcPCO2 measured by ear probe followed PaCO2 one or two minutes later. Therefore, if we measured tcPCO2 one or two minutes later than PaCO2, we could have better correlation and smaller bias and limits of agreement.

The diffusion and production of CO2 in the skin depends on blood flow, metabolism and skin thickness [18]. PaCO2 is reported to be the highest at 30 minutes after pneumoperitoneum and is stable at 60 minutes [19,20]. Our study is the first one to show the time course of tcPCO2 and tcPO2 during pneumoperitoneum, and showed that the correlation between tcPCO2 and PaCO2 was worse and the bias between those was larger at 60 minutes than at 30 minutes of pneumoperitoneum. However, tcPO2 had worse correlation with PaO2 at 30 min. of inflation and improved thereafter. CO2 gradually goes into microcirculation from abdominal cavity, which might increase tcPCO2 faster than PaCO2. Therefore, tcPCO2 became larger than PaCO2 at 60 min. compared to at 30 min. Abdominal inflation distended abdominal wall, which might decrease skin blood flow, then it improved at 60 min., which decreased tcPO2 and correlation between tcPO2 and PaO2 at 30 min. and improved at 60 min.

In conclusion, during laparoscopic surgery, both tcPCO2 and tcPO2 could not be the surrogate measurements of PaCO2 and PaO2, respectively. Correlation between tcPCO2 and PaCO2 decreased according to the duration of pneumoperitoneum. Correlation between tcPO2 and PaO2 decreased during pneumoperitoneum with its peak at 30 min. and improved in 60 min.

Table 1

<table>
<thead>
<tr>
<th>Bias, and Limit of agreement</th>
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<tr>
<th>TCPCO2 - PaCO2</th>
<th>Bias</th>
<th>Limit of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before abdominal inflation</td>
<td>7.8</td>
<td>-0.38, 16.04</td>
</tr>
<tr>
<td>30 min. of inflation</td>
<td>8.7</td>
<td>-8.12, 17.45</td>
</tr>
<tr>
<td>60 min. of inflation</td>
<td>12.3</td>
<td>-8.77, 25.34</td>
</tr>
<tr>
<td>At the end of surgery (after deflation)</td>
<td>8.9</td>
<td>0.11, 17.65</td>
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<th>TCPO2 - PaO2</th>
<th>Bias</th>
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<tbody>
<tr>
<td>Before abdominal inflation</td>
<td>6.3</td>
<td>-5.54, 16.14</td>
</tr>
<tr>
<td>30 min. of inflation</td>
<td>6.4</td>
<td>-0.14, 12.66</td>
</tr>
<tr>
<td>60 min. of inflation</td>
<td>6.3</td>
<td>-4.60, 16.53</td>
</tr>
<tr>
<td>At the end of surgery (after deflation)</td>
<td>2.2</td>
<td>-5.71, 11.11</td>
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<tr>
<th>TCPCO2 - PaCO2</th>
<th>Bias</th>
<th>Limit of agreement</th>
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<tbody>
<tr>
<td>Before abdominal inflation</td>
<td>-0.7</td>
<td>-1.18, 0.6</td>
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<tr>
<td>30 min. of inflation</td>
<td>-177.7</td>
<td>-266.88, -88.45</td>
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<tr>
<td>60 min. of inflation</td>
<td>-155.8</td>
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<tr>
<td>At the end of surgery (after deflation)</td>
<td>-100.35</td>
<td>-177.52, -22.73</td>
</tr>
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Figure 1-3
at 60 min. after start of inflation

![Graph showing the relationship between tPCO2 and tPCO2 (mmHg).](image)

\[ y = 0.2832x + 56.908 \]
\[ R^2 = 0.4118 \]

Figure 2-1
Before inflation (pneumoperitoneum) Solid line, bias; dotted lines, limits of agreement

![Graph showing the relationship between (tPCO2 + PaCO2)/2 (mmHg) and tPCO2 (mmHg).](image)

Figure 1-4
at the end of surgery

![Graph showing the relationship between tPCO2 and tPCO2 (mmHg).](image)

\[ y = 0.5384x + 11.067 \]
\[ R^2 = 0.7647 \]

Figure 2-2
at 30 min. after start of inflation Solid line, bias; dotted lines, limits of agreement

![Graph showing the relationship between (tPCO2 + PaCO2)/2 (mmHg) and tPCO2 (mmHg).](image)
Figure 2-3
at 60 min. after start of inflation Solid line, bias; dotted lines, limits of agreement

Figure 2-4
at the end of surgery Solid line, bias; dotted lines, limits of agreement

Figure 3-1
Before inflation (pneumoperitoneum)

Figure 3-2
at 30 min. after start of inflation
**Figure 3-3**
At 60 min. after start of inflation

**Figure 4-1**
Before inflation (pneumoperitoneum) Solid line, bias; dotted lines, limits of agreement

**Figure 3-4**
At the end of surgery

**Figure 4-2**
At 30 min. after start of inflation Solid line, bias; dotted lines, limits of agreement
Figure 4-3
at 60 min. after start of inflation
Solid line, bias; dotted lines, limits of agreement

Figure 5-1
Before inflation (pneumoperitoneum)

Figure 4-4
at the end of surgery
Solid line, bias; dotted lines, limits of agreement

Figure 5-2
at 30 min. after start of inflation
Figure 5-3
at 60 min. after start of inflation

Figure 6-1
Before inflation (pneumoperitoneum) Solid line, bias; dotted lines, limits of agreement

Figure 5-4
at the end of surgery

Figure 6-2
at 30 min. after start of inflation Solid line, bias; dotted lines, limits of agreement
Figure 6-3
at 60 min. after start of inflation Solid line, bias; dotted lines, limits of agreement

Figure 6-4
at the end of surgery Solid line, bias; dotted lines, limits of agreement

References
12. Weaver L. Transcutaneous oxygen and carbon dioxide tensions compared to arterial blood gases in normals. Respir Care 2007; 52: 1490-1496.
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