Can transcutaneous carbon dioxide and oxygen pressure predict arterial carbon dioxide and oxygen pressure during laparoscopic bariatric surgery?

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ABSTRACT

Objective: In bariatric surgery, arterial carbon dioxide (PaCO2) and oxygen (PaO2) pressures are important but sometimes difficult to measure. The purpose of the present study was to investigate whether transcutaneous carbon dioxide (tcPCO2) and oxygen (tcPO2) pressures can be used to monitor PaCO2 and PaO2, respectively, in laparoscopic bariatric surgery.

Methodology: This non-blind, comparative study was conducted at operating room in the city hospital. Ten adult obese (Body Mass Index (BMI) > 35) patients for laparoscopic bariatric surgery (Bariatric group), and 10 normal weight (BMI < 30) adult patients for open gastric surgery (Control group) were studied. After an epidural catheter insertion at T6-7 or T 7-8, anesthesia was induced with midazolam, propofol, fentanyl, and vecuronium, and was maintained with continuous propofol and remifentanil, intermittent vecuronium and epidural lidocaine. After anesthesia induction, a radial artery catheter was inserted. The electrode of transcutaneous monitor was put on the chest ipsilateral to a radial artery catheter. Pressure controlled ventilation was used in both groups.

During surgery at four random points in each patient samples were drawn for arterial blood gas analysis, and measurements of end-tidal carbon dioxide (EtCO2), tcPO2 and tcPCO2 were performed.

Results: TcPCO2 and PaCO2 in the control group had good correlation, while no correlation was found in the bariatric group. TcPO2 and PaO2, tcPCO2 and EtCO2, and PaCO2 and EtCO2 had no correlation in both groups. The bias and limits of agreement of tcPCO2 - PaCO2, tcPO2 - PaO2, EtCO2 - tcPCO2, and PaCO2 - EtCO2 were larger in the bariatric group than the control group.

Conclusion: Our study concludes that TcPO2 and tcPCO2 cannot be surrogate measurements of PaO2 and PaCO2, respectively in laparoscopic bariatric surgery.

Key words: Obesity; Bariatrics; Bariatric surgery; Laparoscopic surgery; Blood Gas Analysis; Blood Gas Monitoring, Transcutaneous; Oximetry, Transcutaneous; Oxygen Partial Pressure Determination, Transcutaneous; Carbon Dioxide Partial Pressure Determination, Transcutaneous

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INTRODUCTION

The frequency of bariatric surgery is increasing with the ever-increasing number of morbidly obese patients. Laparoscopic procedures are preferred to decrease respiratory depression by postsurgical pain and to get good surgical field.1 In mechanically ventilated morbidly obese patients, functional residual volume decreases and closing capacity becomes high, which leads to a ventilation perfusion mismatch and increased intrapulmonary shunt.2 Therefore, monitoring of arterial oxygen (PaO2) and carbon dioxide (PaCO2) pressures is quite important during general anesthesia. However, in morbidly obese patients, inserting arterial catheter is sometimes difficult and PaO2 and PaCO2 could not be measured continuously. End-tidal CO2 (EtCO2) and
transcutaneous $O_2$ and $CO_2$ in bariatric surgery

Percutaneous oxygen saturation ($SpO_2$) are now usually used to monitor CO$_2$ and O$_2$, respectively, during general anesthesia. $SpO_2$ is sometimes difficult to measure in morbidly obese patients due to thick skin. In morbidly obese patients, reduced functional residual volume with ventilation perfusion mismatch makes EtCO$_2$ incorrect measurement of PaCO$_2$.

Transcutaneous $O_2$ (tcPO$_2$) and $CO_2$ (tcPCO$_2$) pressures are less invasively monitored. There are some studies to investigate whether tcPCO$_2$ could be used as a surrogate measure of PaCO$_2$ in surgery of morbidly obese patients. In addition, tcPO$_2$ has been shown to be more accurate to predict PaCO$_2$ than EtCO$_2$ in laparoscopic surgery. However, there is no study of tcPO$_2$ in surgery of obese patients. Only our previous study investigated tcPO$_2$ in laparoscopic surgery. In that study, tcPO$_2$ had not always good correlation with PaO$_2$.

The purpose of the present study was to investigate whether tcPCO$_2$ and tcPO$_2$ can be used to monitor PaCO$_2$ and PaO$_2$, respectively, in laparoscopic bariatric surgery.

**METHODOLOGY**

After the approval of the ethics committee of the hospital and informed consent from each patient, 10 adult obese (Body Mass Index (BMI) > 35) patients for laparoscopic bariatric surgery (Bariatric group), and 10 normal weight (BMI < 30) adult patients for open gastric surgery (Control group) were enrolled in this study. Those who had severe cardiac, pulmonary, vascular, renal, or liver disease, or who had drug abuse or smoking habit were excluded.

Premedication was not given. An epidural catheter was inserted at T6-7 or T7-8. It was performed using ultrasound guidance in the bariatric group. Anesthesia was induced with midazolam, propofol, and fentanyl. Oro-tracheal intubation was facilitated with vecuronium. Anesthesia was maintained with continuous propofol and remifentanil, and intermittent administration of vecuronium and epidural lidocaine. After anesthesia induction, a radial artery catheter was inserted into right radial artery to perform blood gas analysis. Pressure controlled ventilation was used in both groups basically to keep normal tidal volume as calculated by ideal body weight starting at 10 breaths per minute with 100% oxygen. Then respiratory rate and inspiratory pressure were changed for the study.

The electrode of TCM4™ (Radiometer, Copenhagen, Denmark) heated at 43 degrees Celsius was put on the chest ipsilateral to a radial artery catheter. At four random points during surgery in each patient, samples were drawn for arterial blood gas analysis, then measurements of end-tidal carbon dioxide pressure (EtCO$_2$), percutaneous oxygen (tcPO$_2$) and carbon dioxide (tcPCO$_2$) pressure were noted.

Power analysis was performed to detect $R^2$ value of 0.75 with the power of 0.95 (G Power™ software, University Mannheim, Germany). Statistical analysis was performed with chi-square test and factorial analysis of variance for demographic data. A p-value less than 0.05 was considered to be significant difference. To judge the accuracy of tcPCO$_2$ and tcPO$_2$, the Bland-Altman plot and linear regression analysis were performed.

**RESULTS**

The power analysis showed that 10 patients were necessary to detect $R^2$ of 0.75. Therefore, we included 10 patients in each group. Demographic data were not different between the two groups except for body mass index (Table 1).

**Table 1: Demographic data**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Obese Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/Female</td>
<td>4/6</td>
<td>5/5</td>
</tr>
<tr>
<td>Age (years)</td>
<td>39.2 (21-60)</td>
<td>44.8 (25-62)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>169.1 (153.0-181.0)</td>
<td>167.8 (158.9-174.0)</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>144.4 (102.3-206.0)*</td>
<td>65.5 (55.5-72.0)</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>50.8 (40.3-82.5)*</td>
<td>23.2 (22.0-24.1)</td>
</tr>
<tr>
<td>Duration of anesthesia (min)</td>
<td>285 (165-385)</td>
<td>262 (155-375)</td>
</tr>
</tbody>
</table>

Data given as number of the patients or mean with range in the parenthesis.

*: $P < 0.05$ vs. Control group

TcPCO$_2$ and PaCO$_2$ in the control group had good correlation (Figure1-1), while no correlation was found between tcPCO$_2$ and PaCO$_2$ in the bariatric group (Table 2, Figure 1-2). TcPO$_2$ and PaO$_2$ (Figure 3), tcPCO$_2$ and EtCO$_2$, and PaCO$_2$ and EtCO$_2$ had no correlation in both groups (Table 2), while coefficient of determination ($R^2$) of these were higher in the control group than the bariatric group.

The bias and limits of agreement were small enough to be surrogate measurement for tcPCO$_2$ and PaCO$_2$ in the control group (Figure 2-1). The bias and limits of agreement of tcPCO$_2$ - PaCO$_2$, tcPO$_2$ - PaO$_2$, EtCO$_2$ - tcPCO$_2$, and PaCO$_2$ - EtCO$_2$ were larger in the bariatric group than the control group (Table 2, Figure 2-2, 4-1, 4-2).
Table 2: Correlation coefficient, bias, and limits of agreement

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>Bias</th>
<th>Limits of agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO₂-tcPO₂</td>
<td>0.63</td>
<td>67.6</td>
<td>-6.1, 141.4</td>
</tr>
<tr>
<td>PaCO₂-tcPCO₂</td>
<td>0.83</td>
<td>-0.95</td>
<td>-4.3, 2.5</td>
</tr>
<tr>
<td>EtCO₂-tcPCO₂</td>
<td>0.48</td>
<td>-5.1</td>
<td>-11.9, 1.6</td>
</tr>
<tr>
<td>PaCO₂-EtCO₂</td>
<td>0.66</td>
<td>4.2</td>
<td>-1.6, 10.0</td>
</tr>
<tr>
<td><strong>Bariatric</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PaO₂-tcPO₂</td>
<td>0.25</td>
<td>147.4</td>
<td>-31.2, 326.1</td>
</tr>
<tr>
<td>PaCO₂-tcPCO₂</td>
<td>0.43</td>
<td>-2.2</td>
<td>-18.7, 14.3</td>
</tr>
<tr>
<td>EtCO₂-tcPCO₂</td>
<td>0.27</td>
<td>-10.5</td>
<td>-24.3, 3.2</td>
</tr>
<tr>
<td>PaCO₂-EtCO₂</td>
<td>0.31</td>
<td>8.3</td>
<td>-3.6, 20.3</td>
</tr>
</tbody>
</table>

DISCUSSION

The present study showed that tcPO₂ and tcPCO₂ had no correlation and had large bias and limits of agreement with PaO₂ and PaCO₂, respectively in laparoscopic bariatric surgery.

For measurement of tcPCO₂, chest probe was proved to be better than ear probe to get good correlation with PaCO₂. When the electrode of the TCM was put on the chest, tcPO₂ and tcPCO₂ well correlated with PaO₂ and PaCO₂ respectively in our previous study. Therefore, we used chest probe. The electrode of the TCM should be heated to 43°C to measure tcPO₂ and tcPCO₂ as we did in the present study.

There are some limitations of this study. We used pressure controlled ventilation in both groups, while the pressure settings were quite variable. In some cases, ephedrine was administered to increase blood pressure as a bolus. We could not control body temperature strictly, while we used warming blankets. However, catecholamine, respiratory support or hypothermia did not have any influence on the accuracy of tcPCO₂ measure.

In addition, it should take 1 or 2 minutes for tcPCO₂ to reflect PaCO₂ but no strict delay was noticed. Therefore, after drawing the blood for arterial blood gas analysis, we measured tcPCO₂, tcPO₂, and EtCO₂ but this might not be enough for the necessary time lag.

In laparoscopic surgery, tcPCO₂ correlated well with PaCO₂ except for during abdominal inflation, EtCO₂ correlated well with PaCO₂ only before inflation, and tcPO₂ correlated well with PaO₂ except
transcutaneous $O_2$ and $CO_2$ in bariatric surgery

- The CO$_2$ pneumoperitoneum results in the further decrease of functional residual capacity and greater degree of intrapulmonary shunt, which diminishes the accuracy of EtCO$_2$. The CO$_2$ partial pressure was at its highest 30 minutes after pneumoperitoneum and was stable 60 minutes after pneumoperitoneum. Therefore, as in our results, EtCO$_2$ did not correlate well with PaCO$_2$.

- TcPCO$_2$ and tcPO$_2$ did not correlate with PaCO$_2$ and PaO$_2$, respectively, when PaCO$_2$ > 56 mmHg and PaO$_2$ > 115 mmHg. Almost all of the data in the present study showed PaO$_2$ > 115 mmHg, but PaCO$_2$ < 56 mmHg. Therefore, tCPCO$_2$ should correlate well with PaCO$_2$, but it was not in the present study.

- TcPCO$_2$ was reported to be better than EtCO$_2$ to estimate PaCO$_2$ for early phase of inflation in our previous study. TcPCO$_2$ and EtCO$_2$, and tCPO$_2$ could not be surrogate measurement of PaCO$_2$ and PaO$_2$, respectively in laparoscopic surgery. EtCO$_2$ may not reflect changes in PaCO$_2$ during inflation because of changes in alveolar dead space, consequent to reduced cardiac output, increased ventilation-perfusion mismatching. The CO$_2$ pneumoperitoneum results in the further decrease of functional residual capacity and greater degree of intrapulmonary shunt, which diminishes the accuracy of EtCO$_2$. The CO$_2$ partial pressure was at its highest 30 minutes after pneumoperitoneum and was stable 60 minutes after pneumoperitoneum. Therefore, as in our results, EtCO$_2$ did not correlate well with PaCO$_2$.

- The relation between tCPCO$_2$ and PaCO$_2$, and tCPO$_2$ and PaO$_2$ are different in different phases of pneumoperitoneum. However, in the present study, we measured these at random, not according to the time course of the pneumoperitoneum because the purpose of this study was to know whether tCPCO$_2$ and tCPO$_2$ could be used to monitor PaCO$_2$ and PaO$_2$, respectively, not to know the difference according to the phases of pneumoperitoneum.
in obese patients undergoing open\(^5\) and laparoscopic\(^6\) bariatric surgery. Dion et al showed that both tcPCO\(_2\) and EtCO\(_2\) had good correlation and lower bias and precision with PaCO\(_2\) in laparoscopic bariatric surgery.\(^7\) The differences between tcPCO\(_2\) and EtCO\(_2\), and EtCO\(_2\) and PaCO\(_2\) in their study were quite smaller than those in our present study, and also than those in our previous studies in non-obese patients.\(^8\)-\(^11\) Although we could not know why they had so small differences, but from all of our data including non-obese subjects, we could not say that tcPCO\(_2\) and EtCO\(_2\) were accurate measurements of PaCO\(_2\) during general anesthesia, especially in obese patients.

Bernhardt et al. showed that PjCO\(_2\) (5.5 + 0.9 x EtCO\(_2\) – 2.1 x tidal volume (L)) could be used for accurate estimation of PaCO\(_2\) in morbidly obese adults.\(^18\) However, this calculation is complicated not to be done instantly. Therefore, this is not clinically useful.

There has been no studies of tcPO\(_2\) in bariatric laparoscopic surgery. A thicker epidermal layer led to greater difference between PtcO\(_2\) and PaO\(_2\).\(^12\) Adiposity impairs the diffusion of oxygen through the skin.\(^19\) Therefore, our results showed tcPO\(_2\) could not show PaO\(_2\).

CONCLUSION

On the basis of the results of our study, we conclude that tcPO\(_2\) and tcPCO\(_2\) cannot be surrogate measurements of PaO\(_2\) and PaCO\(_2\), respectively in laparoscopic bariatric surgery.

Conflict of interest: Nil
transcutaneous $\text{O}_2$ and $\text{CO}_2$ in bariatric surgery

REFERENCES