ORIGINAL ARTICLE

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 ($PaCO_2$) and oxygen (PaO_2) pressures are important but sometimes difficult to measure. The purpose of the present study was to investigate whether transcutaneous carbon dioxide ($tcPCO_2$) and oxygen ($tcPO_2$) pressures can be used to monitor $PaCO_2$ and PaO_2, respectively, in laparoscopic bariatric surgery.

Methodology: This non-blind, comparadive 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 ($EtCO_2$), $tcPO_2$ and $tcPCO_2$ were performed.

Results: $TcPCO_2$ and $PaCO_2$ in the control group had good correlation, while no correlation was found in the bariatric group. $TcPO_2$ and PaO_2, $tcPCO_2$ and $EtCO_2$, and $PaCO_2$ and $EtCO_2$ had no correlation in both groups. 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.

Conclusion: Our study concludes that $TcPO_2$ and $tcPCO_2$ cannot be surrogate measurements of PaO_2 and $PaCO_2$, 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 (PaO_2) and carbon dioxide ($PaCO_2$) pressures is quite important during general anesthesia. However, in morbidly obese patients, inserting arterial catheter is sometimes difficult and PaO_2 and $PaCO_2$ could not be measured continuously. End-tidal CO_2 ($EtCO_2$) and

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 $PaCO_2$.[3]

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.[4,5] In addition, $tcPCO_2$ has been shown to be more accurate to predict $PaCO_2$ than $EtCO_2$ in laparoscopic surgery.[6,7] However, there is no study of $tcPO_2$ in surgery of obese patients. Only our previous study[8] 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

Parameter	Obese Group	Control Group
Male/Female	4/6	5/5
Age (years)	39.2 (21-60)	44.8 (25-62)
Height (cm)	169.1 (153.0-181.0)	167.8 (158.9-174.0)
Body weight (kg)	144.4 (102.3-206.0)*	65.5 (55.5-72.0)
Body mass index (kg/m^2)	50.8 (40.3-82.5)*	23.2 (22.0-24.1)
Duration of anesthesia (min)	285 (165-385)	262 (155-375)

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

	R^2	Bias	Limits of agreement
Control			
PaO_2-$tcPO_2$	0.63	67.6	-6.1, 141.4
$PaCO_2$-$tcPCO_2$	0.83	-0.95	-4.3, 2.5
$EtCO_2$-$tcPCO_2$	0.48	-5.1	-11.9, 1.6
$PaCO_2$-$EtCO_2$	0.66	4.2	-1.6, 10.0
Bariatric			
PaO_2-$tcPO_2$	0.25	147.4	-31.2, 326.1
$PaCO_2$-$tcPCO_2$	0.43	-2.2	-18.7, 14.3
$EtCO_2$-$tcPCO_2$	0.27	-10.5	-24.3, 3.2
$PaCO_2$-$EtCO_2$	0.31	8.3	-3.6, 20.3

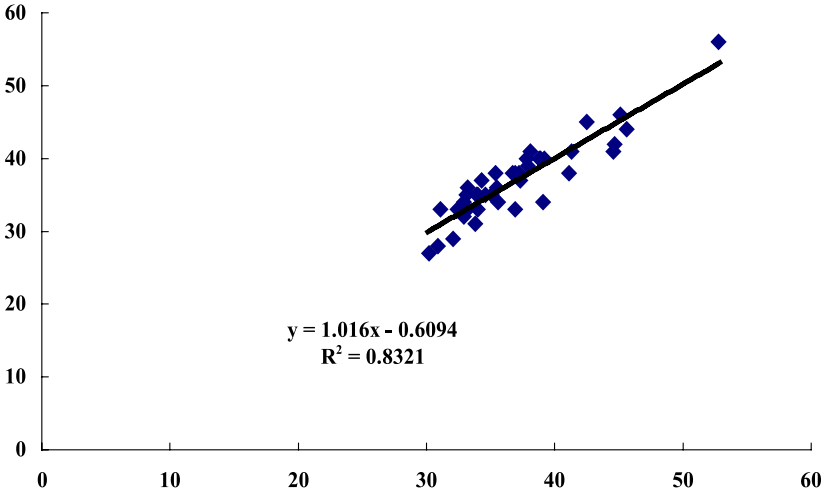

Figure1-1: Correlation between $tcPCO_2$ and $PaCO_2$ - Control group

Positive correlation was found.

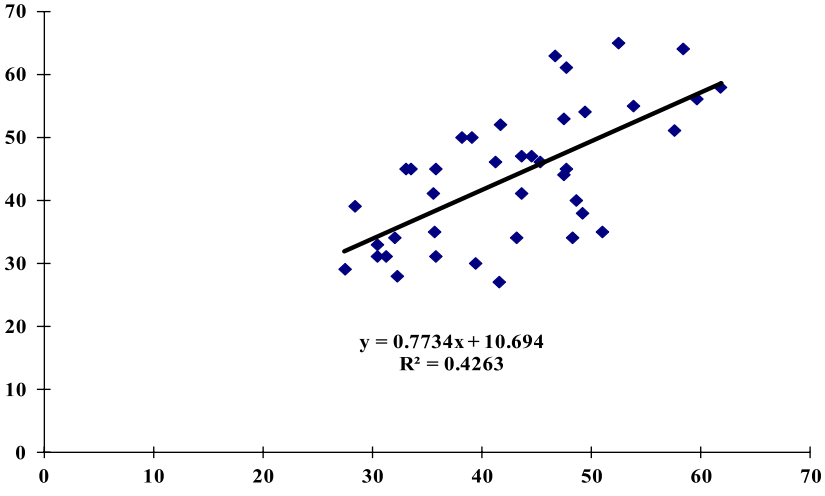

Figure1-2: Correlation between $tcPCO_2$ and $PaCO_2$ - Bariatric group

DISCUSSION

The present study showed that $tcPO_2$ and $tcPCO_2$ had no correlation and had large bias and limits of agreement with PaO_2 and $PaCO_2$, respectively in laparoscopic bariatric surgery.

For measurement of $tcPCO_2$, chest probe was proved to be better than ear probe to get good correlation with $PaCO_2$.[2] When the electrode of the TCM was put on the chest, $tcPO_2$ and $tcPCO_2$ well correlated with PaO_2 and $PaCO_2$, respectively in our previous study.[10] Therefore, we used chest probe. The electrode of the TCM should be heated to 43ª C to measure $tcPO_2$ and $tcPCO_2$[11] 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 $tcPCO_2$ measure.[12] In addition, it should take 1 or 2 minutes for $tcPCO_2$ to reflect $PaCO_2$, but no strict delay was noticed.[13] Therefore, after drawing the blood for arterial blood gas analysis, we measured $tcPCO_2$, $tcPO_2$, and $EtCO_2$, but this might not be enough for the necessary time lag.

In laparoscopic surgery, $tcPCO_2$ correlated well with $PaCO_2$ except for during abdominal inflation, $EtCO_2$ correlated well with $PaCO_2$ only before inflation, and $tcPO_2$ correlated well with PaO_2 except

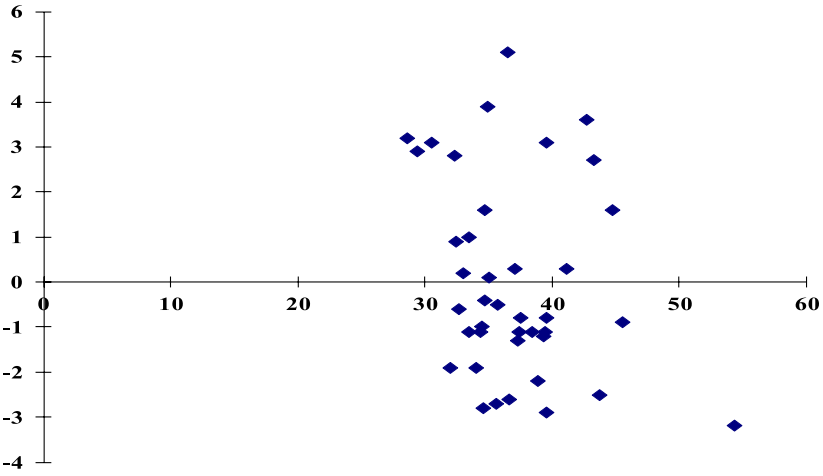

Figure 2-1: Bland-Altman plot of $tcPCO_2$ and $PaCO_2$ - Control group

Low bias and good limits of agreement were found.

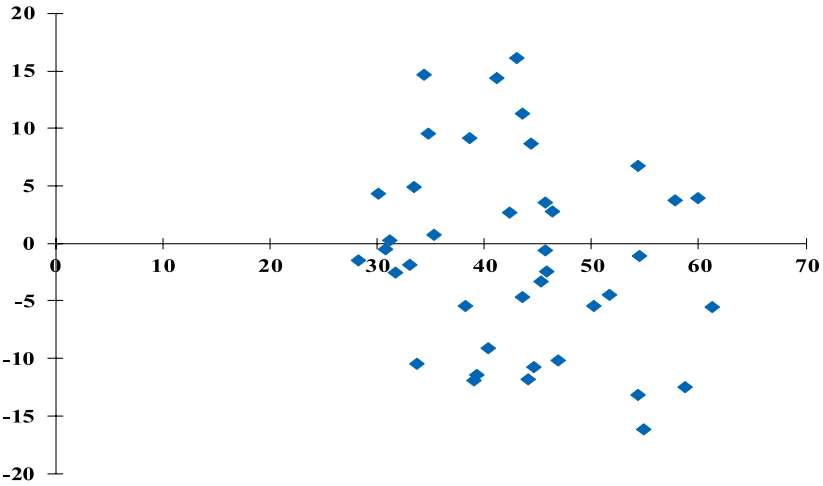

Figure 2-2: Bland-Altman plot of $tcPCO_2$ and $PaCO_2$ - Bariatric group

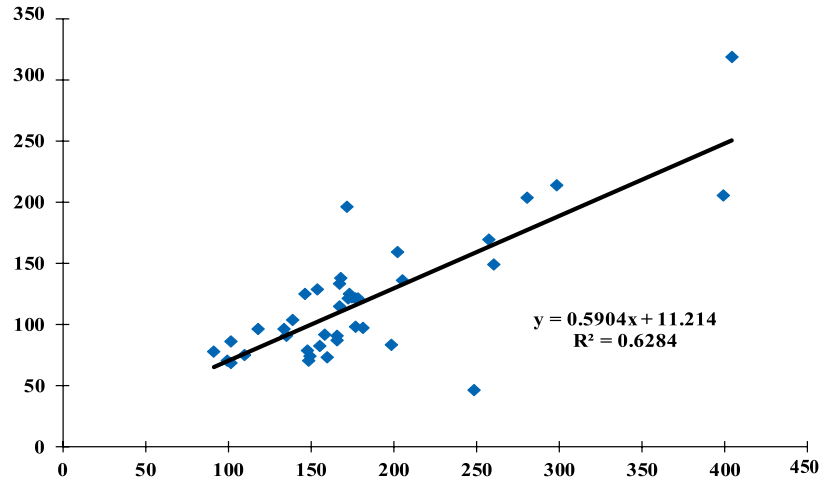

Figure 3-1: Correlation between $tcPO_2$ and PaO_2 - Control group

for early phase of inflation in our previous study.[8] $TcPCO_2$ and $EtCO_2$, and $tcPO_2$ could not be surrogate measurement of $PaCO_2$ and PaO_2, respectively in laparoscopic surgery.[8] $EtCO_2$ 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.[14] 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.[15] 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.

$TcPCO_2$ and $tcPO_2$ did not correlate with $PaCO_2$ and PaO_2, respectively, when $PaCO_2 > 56$ mmHg and $PaO_2 > 115$ mmHg.[16] 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 $PaCO_2$

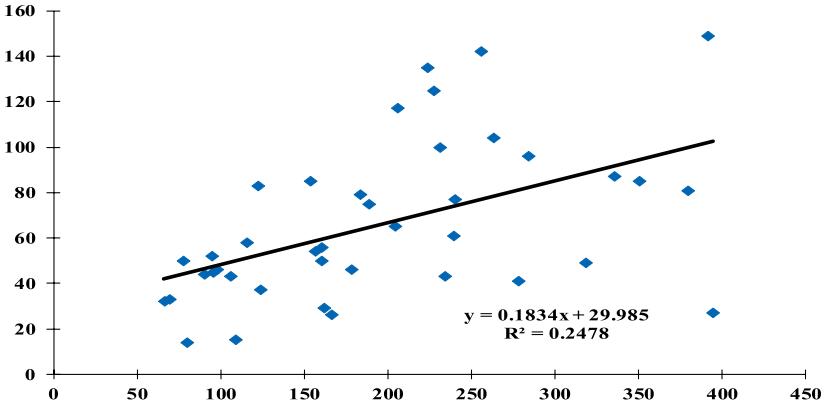

Figure 3-2: Correlation between $tcPO_2$ and PaO_2 - Bariatric group

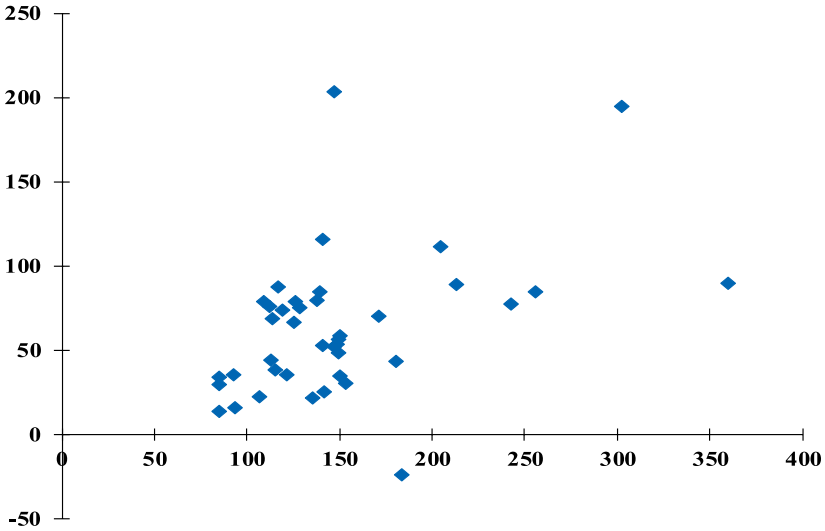

Figure 4-1: Bland-Altman plot of $tcPO_2$ and PaO_2 - Control group

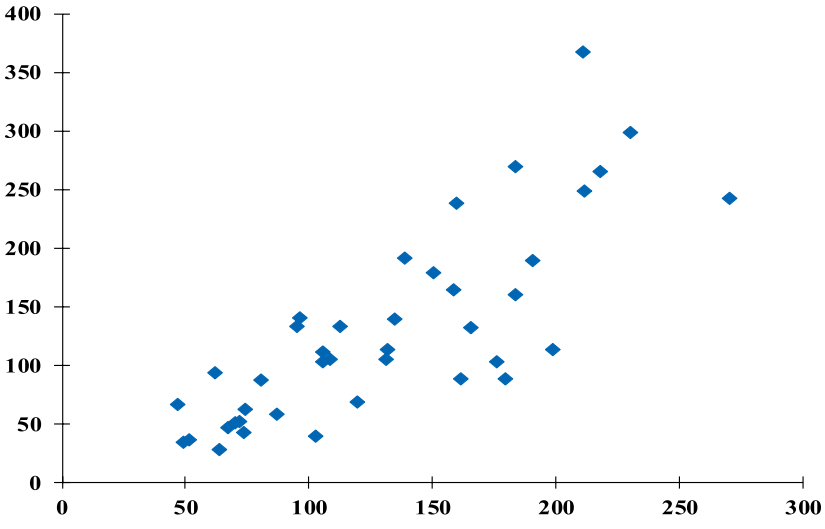

Figure 4-2: Bland-Altman plot of $tcPO_2$ and PaO_2 - Bariatric group

in obese patients undergoing open[4] and laparoscopic[5] 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.[17] 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, out 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

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