Arterial and end-tidal carbon dioxide pressure differences during laparoscopic colorectal surgery

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EDITOR:
Because laparoscopy with carbon dioxide (CO_2) pneumoperitoneum increases CO_2 loading by transperitoneal absorption and decreases both thoracic compliance and functional residual capacity (FRC), arterial ($PaCO_2$) and end-tidal ($P_{ET}CO_2$) carbon dioxide can increase during laparoscopy. These can be affected by the duration of pneumoperitoneum and body position. $P_{ET}CO_2$ is widely used as an indicator of $PaCO_2$ and hence adequacy of ventilation during laparoscopic surgery. However, careful consideration should be taken of the gradient between $PaCO_2$ and $P_{ET}CO_2$ ($P(a-ET)CO_2$) because $P_{ET}CO_2$ may not reflect $PaCO_2$ because of ventilation perfusion mismatching. $P(a-ET)CO_2$ either remains unchanged or may increase during laparoscopy, with an exaggerated response in the presence of cardiopulmonary disease [1].

In previous studies, $P(a-ET)CO_2$ during laparoscopic surgery has been reported for short or intermediate durations of surgery [1,2], but not for prolonged durations of surgery. Laparoscopic colorectal surgery takes at least 5 h, and positioning in both Trendelenburg and reverse-Trendelenburg is required. The purpose of this study was to assess the effect of CO_2 pneumoperitoneum on the $P(a-ET)CO_2$ gradient during prolonged pneumoperitoneum for laparoscopic colorectal surgery.

Sixteen healthy patients (12 males; 4 females), ASA physical status I (10 patients) or II (6 patients), scheduled for laparoscopic colorectal surgery were studied. The study was approved by the hospital Ethics Committee and written and informed consent was obtained from each patient. Patients with cardiopulmonary abnormality were excluded.

Patients received lidocaine $1\,mg\,kg^{-1}$, propofol $2–2.5\,mg\,kg^{-1}$ and rocuronium $0.8\,mg\,kg^{-1}$ for induction of anaesthesia. After tracheal intubation, anaesthesia was maintained with 50% nitrous oxide and enflurane in oxygen with rocuronium for muscle relaxation.

A Drager capnograph (Drager Medical System, Danvers, MA, USA) was used to monitor the $P_{ET}CO_2$. Mechanical ventilation was used with a tidal volume of $8–10\,ml\,kg^{-1}$ and a rate of 10–14 breaths min^{-1} to maintain $P_{ET}CO_2$ at a stable value between 30 and 40 mmHg during the procedure (inspiratory time : expiratory time ratio 1 : 2). After induction of general anaesthesia, a 22-G arterial cannula was introduced into the left radial artery after modified Allen's test. A baseline (preinsufflation) arterial blood sample was taken for arterial CO_2 tension measurement. Peritoneal insufflation of CO_2 was then commenced and arterial blood samples repeated at 10, 60 and 120 min after CO_2 insufflation, and 10 min after the termination of insufflation. During surgery, the $P_{ET}CO_2$ was monitored continuously. During the laparoscopic procedure, the intra-abdominal pressure was automatically maintained at 12 mmHg by a CO_2 insufflator (Stryker Endoscopy; Roissy Ch. de Gaulle, France). Arterial blood gas analysis was performed using a Nova blood gas analyser (Nova Biomedical, Waltham, MA, USA) after calibration. All patients were placed in a 20° Trendelenburg position with left tilt and then changed to 20° reverse-Trendelenburg position with left tilt during the surgery. Repeated measures ANOVA and *t*-test were used as appropriate for analysis; $P < 0.01$ was considered significant.

There were three cases of laparoscopic transanal protosigmoidectomy and 13 cases of laparoscopic low anterior resection. The mean ± SD age of the patients was 51 ± 12 yr, duration of anaesthesia 357 ±127 min and the first insufflation period 152 ± 70 min. There were significant increases in the mean $P_{ET}CO_2$ and $PaCO_2$ during CO_2 pneumoperitoneum as compared with before pneumoperitoneum ($P < 0.01$, Table 1). The $P(a-ET)CO_2$ increased significantly with time ($P < 0.01$, Table 1).

CO_2 gas is most commonly used in laparoscopic surgery because it is soluble in blood, well diffused into organ tissues, has less risk of gas

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Table 1. Changes in arterial and end-tidal CO_2 tension.

	$PaCO_2$	$P_{ET}CO_2$	$P(a-ET)CO_2$
Preinsufflation	31.1 ± 3.6	30.8 ± 1.5	0.3 ± 3.4
Pneumoperitoneum 10 min	$35.7 \pm 3.6^*$	$32.8 \pm 1.7^*$	$2.9 \pm 3.6^*$
Pneumoperitoneum 60 min	$35.8 \pm 3.6^*$	$33.0 \pm 1.9^*$	$2.8 \pm 3.7^*$
Pneumoperitoneum 120 min	$38.0 \pm 4.9^*$	$33.9 \pm 3.1^*$	$4.1 \pm 3.5^*$
10 min after CO_2 release	34.2 ± 4.1	31.7 ± 2.3	2.6 ± 3.4

Data are expressed as mean ± SD.
$^*P < 0.01$ as compared with preinsufflation value.

embolism and has no risk of an explosion. It may cause hypercarbia and respiratory acidosis due to the absorption of CO_2 [3]. In healthy patients, however, excess CO_2 can be easily washed out by alveolar ventilation, resulting in only mild hypercarbia and an increased $_{ET}CO_2$ tension. These studies were reported in relatively short duration of surgery, e.g. laparoscopic cholecystectomy. In our study, the $P_{ET}CO_2$ was maintained in the normal range by increasing the minute volume. However, the mean values of $P_{ET}CO_2$ during pneumoperitoneum were significantly higher than the $P_{ET}CO_2$ before insufflation.

The $PaCO_2$ during pneumoperitoneum, also, was significantly higher than $PaCO_2$ before insufflation. Taura and colleagues [4] reported the results of arterial blood gas analysis in patients during laparoscopic sigmoidectomy. The mean operation time was 4 h and the $PaCO_2$ at 90 min after insufflation, 5 min before termination of insufflation and at 60 min postoperatively were higher than the baseline.

The $P(a-ET)CO_2$ is dependent on many factors including the relative distribution of ventilation and perfusion within the lung, changes in FRC and changes in CO_2 production (VCO_2). Trendelenburg positioning together with peritoneal insufflation of CO_2 during laparoscopy reduces the FRC and increases the VCO_2. In addition, there may be a change in the V/Q distribution due to basal lung compression and redistribution of hydrostatic forces. Thus, $P(a-ET)CO_2$ may be expected to change. On the contrary, increased FRC may offset decreased pulmonary ventilation due to pneumoperitoneum during reverse-Trendelenburg positioning.

In our study, the $P(a-ET)CO_2$ significantly increased during pneumoperitoneum and was highest at 120 min after pneumoperitoneum, as compared with before pneumoperitoneum.

Our results were different from those of Tanaka and colleagues [5] who reported that the $P(a-ET)CO_2$ increased significantly during pneumoperitoneum during laparoscopic colorectal surgery, but did not increase further even if CO_2 insufflation was longer than 60 min. The intra-abdominal pressure was maintained at 7–10 mmHg in their studies whereas in our study it was 12 mmHg. The higher pressure in our study might have been the cause of different results between two studies. In conclusion, during laparoscopic colorectal surgery with prolonged CO_2 pneumoperitoneum, $PaCO_2$ should be checked intermittently to confirm adequate ventilation.

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