Comparison of Transcutaneous, Arterial and End-tidal Measurements of Carbon Dioxide during Laparoscopic Cholecystectomy in Patients with Chronic Obstructive Pulmonary Disease

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OBJECTIVE: Transcutaneous, arterial and end-tidal measurements of carbon dioxide were compared in patients (American Society of Anesthesiology physical status classes II and III) with chronic obstructive pulmonary disease (COPD) who underwent laparoscopic cholecystectomy with carbon dioxide insufflation. METHODS: General anaesthesia was performed in all patients. The Sentec ® system was used for transcutaneous monitoring of the partial pressure of carbon dioxide (TcPCO₂). TcPCO₂ and arterial partial pressure of carbon dioxide (PaCO₂) were recorded preoperatively, after induction of anaesthesia, during insufflation and postoperatively; end-tidal carbon dioxide (ETCO₂) was recorded after induction and during insufflation. RESULTS: PaCO₂ increased during insufflation and reached a maximum at extubation. It declined within 20 min postoperatively but did not return to preoperative levels during this time. TcPCO₂ levels followed a similar pattern. ETCO₂ was significantly lower than PaCO₂ after induction and during insufflation. CONCLUSION: TcPCO₂ was a valid and practical measurement compared with ETCO₂. In patients with COPD undergoing laparoscopic cholecystectomy, TcPCO₂ and ETCO₂ could be used instead of arterial blood gas sampling.

KEY WORDS: CHRONIC OBSTRUCTIVE PULMONARY DISEASE; LAPAROSCOPIC CHOLECYSTECTOMY; INSUFFLATION; ARTERIAL CARBON DIOXIDE; END-TIDAL CARBON DIOXIDE; TRANSCUTANEOUS CARBON DIOXIDE

Introduction

A pneumoperitoneum is produced by insufflation with carbon dioxide during laparoscopic cholecystectomy. Cardiovascular and pulmonary systems can be adversely affected by insufflation of carbon dioxide into the peritoneal space.¹ The adequacy of ventilation during general anaesthesia can be assessed by monitoring the arterial partial pressure of carbon dioxide (PaCO₂) or end-tidal carbon dioxide (ETCO₂), or by transcutaneous carbon dioxide monitoring. Monitoring of abdominal carbon dioxide insufflation is more
important in patients with chronic obstructive pulmonary disease (COPD) than in patients without this disease due to increases in physiological dead space. Monitoring the transcutaneous partial pressure of carbon dioxide (TcPCO$_2$) by a noninvasive method has been found to give results similar to those obtained with an invasive monitoring method.$^2$

The present study examined the monitoring carbon dioxide using the three different methods of PaCO$_2$, ETCO$_2$ and TcPCO$_2$ before, during and after surgery in patients with COPD undergoing elective laparoscopic cholecystectomy for cholelithiasis.

**Patients and methods**

**STUDY POPULATION**

Patients attending the Department of Respiratory and Emergency Medicine who were scheduled to undergo elective laparoscopic cholecystectomy for cholelithiasis at the Department of Surgery and Anaesthesiology, Istanbul Educational and Research Hospital, Istanbul, Turkey, between November 2005 and November 2006 were eligible for enrolment in this study. Participants were required to be of American Society of Anesthesiology (ASA) physical status class II or class III. Exclusion criteria included anticipation of a difficult airway and history of cardiac disease or psychiatric illness.

The study was approved by the Ethics Committee of Istanbul Educational and Research Hospital, Istanbul, Turkey, and written informed consent was obtained from all the patients included in the study.

**PROCEDURES AND ASSESSMENTS**

During the operation all patients were monitored for vital parameters by electrocardiography, peripheral oxygen saturation (SpO$_2$) by pulse oximetry, and their invasive systemic blood pressure was monitored. Left or right radial artery cannulation was performed for the measurement of PaCO$_2$ after carrying out the Allen's test. The right or left earlobe of each patient was cleaned with alcohol and a Sentec® Digital Monitoring System (SenTec AG, Therwil, Switzerland) was used for transcutaneous monitoring of the partial pressure of carbon dioxide (TcPCO$_2$).

Train-of-four monitoring was used to determine the degree of curarization. Anaesthesia was induced with 1.5 µg/kg fentanyl, 2.5 mg/kg propofol and 0.1 mg/kg vecuronium. Orotracheal intubation was performed following 100% oxygenation for 90 – 120 s. Anaesthesia was maintained with 1 – 3% sevoflurane in a mixture of 50% oxygen/50% nitrous oxide.

Laparoscopic cholecystectomy was performed according to a standard four-port technique in all patients in the reverse Trendelenburg position with left tilt. Pneumoperitoneum was produced by peritoneal insufflation with carbon dioxide over a period of approximately 1 min through a needle inserted below the umbilicus with the patient in a horizontal position. The carbon dioxide was insufflated to an abdominal pressure of 12 mmHg and automatically maintained at this pressure for the duration of the procedure. Sevoflurane anaesthesia was discontinued at the time of skin closure. Any residual muscle relaxation was antagonized with 0.02 mg/kg atropine and 0.04 mg/kg neostigmine at the end of the operation.

Measurements of TcPCO$_2$, PaCO$_2$, arterial partial pressure of oxygen (PaO$_2$), arterial oxygen saturation (SaO$_2$) and Spo$_2$ were recorded preoperatively. TcPCO$_2$, PaCO$_2$ and ETCO$_2$ were recorded 5 min after induction of anaesthesia and at 5 and 20 min of
insufflation. In addition, TcPCO₂ and PaCO₂ were measured at 5 min after extubation and in the recovery room 20 min postoperatively.

**STATISTICAL ANALYSES**

All statistical analyses were performed using SPSS® statistical software, version 11.5 (SPSS Inc., Chicago, IL, USA) for Windows®. Student’s t-test was used to assess differences between groups and the paired t-test was used to assess within-group differences at the various time-points. A P-value of < 0.05 was considered statistically significant.

**Results**

A total of 30 patients (10 males [33.3%] and 20 females [66.6%]) with COPD underwent laparoscopic cholecystectomy in the present study. The mean ± SD age of the patients was 55.8 ± 9.7 years, body mass index was 26.0 ± 2.5 kg/m² and duration of surgery was 51.2 ± 20.0 min.

The levels of TcPCO₂, PaCO₂ and ETCO₂ at the various time-points during the study are shown in Table 1. The TcPCO₂ during insufflation, after extubation and in the postoperative period was significantly higher than the level recorded 5 min after induction of anaesthesia (P < 0.05) and compared with the preoperative level (P < 0.05). TcPCO₂ was also significantly higher at 20 min of insufflation compared with 5 min of insufflation (P < 0.05). The level of PaCO₂ was higher at 5 min of insufflation compared with the preoperative level, but this was not statistically significant (Table 1). Compared with 5 min after induction or at 5 min of insufflation, PaCO₂ was significantly higher at 20 min of insufflation, after extubation and in the postoperative period (P < 0.05 for all). A significant increase in PaCO₂ also occurred after 20 min of insufflation, after extubation and postoperatively compared with the preoperative level (P < 0.05). ETCO₂ was significantly higher at 5 and 20 min of insufflation compared with 5 min after induction (P < 0.05).

Comparisons between recorded variables showed that TcPCO₂ and PaCO₂ did not differ significantly at 5 min after induction of anaesthesia, at 20 min of insufflation or at 5 min after extubation (Table 1). PaCO₂ was significantly higher than ETCO₂ at 5 min after induction of anaesthesia, and at 5 and 20 min of insufflation (P < 0.05).

| Time-point               | TcPCO₂, mmHg | PaCO₂, mmHg | ETCO₂, mmHg |
|-------------------------|--------------|-------------|-------------|
| Preoperative            | 36.07 ± 2.98 | 36.95 ± 3.88| ND          |
| 5 min after induction of anaesthesia | 36.89 ± 4.69 | 36.19 ± 4.70 | 33.20 ± 4.29d |
| 5 min of insufflation   | 38.36 ± 6.04a,b | 38.44 ± 5.95 | 34.77 ± 5.10b,d |
| 20 min of insufflation  | 42.30 ± 6.93a,b,c | 40.79 ± 5.74a,b,c | 37.33 ± 5.60b,d |
| 5 min after extubation  | 49.77 ± 8.20a,b | 49.92 ± 9.45a,b,c | ND          |
| 20 min postoperatively  | 40.94 ± 7.74a,b | 42.29 ± 7.35a,b,c | ND          |

Data presented as mean ± SD.

P < 0.05: a versus preoperative; b versus 5 min after induction of anaesthesia; c versus 5 min of insufflation; d versus PaCO₂ (Student’s t-test for between-group differences and paired t-test for within-group differences at the various time-points).

ND, not determined.
Discussion
Creating a pneumoperitoneum improves intra-abdominal visualization and provides sufficient working space to conduct laparoscopic cholecystectomy. Intra-abdominal and intrathoracic pressures, however, increase with intra-abdominal insufflation with carbon dioxide in proportion to the volume of gas that is delivered. This causes restricted diaphragm motion, and reduced lung compliance and vital capacity. As a consequence functional residual capacity is reduced, alveolar dead space increases pulmonary atelectasis and high airway pressure occurs. Furthermore, carbon dioxide is absorbed into the blood due to the large difference in partial pressures that arise between the pneumoperitoneum and the blood perfusing the peritoneum. This causes hypercarbia and acidosis, an effect that can be more pronounced in patients with underlying cardiovascular or respiratory disease.

Numerous studies have demonstrated changes in carbon dioxide parameters in patients undergoing laparoscopy. A significant increase in PaCO$_2$ together with acidosis was observed in a study evaluating the use of carbon dioxide to create a pneumoperitoneum in patients undergoing diagnostic laparoscopy. Another study in 16 otherwise healthy subjects undergoing laparoscopic cholecystectomy, found that ETCO$_2$ increased from 31.4 to 42.1 mmHg and PaCO$_2$ increased from 33.3 to 43.7 mmHg during the procedure. These changes were accompanied by a decrease in arterial pH from 7.43 to 7.34. Similarly, an increase in PaCO$_2$ and ETCO$_2$ and a consequent decrease in arterial pH were reported in a study examining respiratory mechanics and arterial blood gases in patients undergoing laparoscopic cholecystectomy with carbon dioxide insufflation. The findings of the present study are consistent, therefore, with previous research in showing that ETCO$_2$ and PaCO$_2$ increased during laparoscopic cholecystectomy with carbon dioxide insufflation.

Careful monitoring of patients, both pre- and postoperatively, for the effects of hypercarbia is advocated by previous research, particularly in patients with comorbid cardiopulmonary disease. In a study involving patients undergoing laparoscopic cholecystectomy with and without underlying cardiopulmonary disease, greater increases in PaCO$_2$ and decreases in pH were observed after insufflation in patients with comorbid disease compared with patients without underlying disease. Taking these data and the findings of the present study together suggests that careful follow-up is warranted in patients with COPD who undergo laparoscopic cholecystectomy with carbon dioxide insufflation. Gas monitoring is also important in the postoperative period, as demonstrated in a study comparing gas parameters in patients who underwent laparoscopic cholecystectomy or open cholecystectomy. ETCO$_2$, measured using an intranasal catheter, was significantly higher in extubated patients after laparoscopic cholecystectomy compared with after open cholecystectomy (46 versus 36 mmHg, respectively) and declined to 40 mmHg within 3 h after laparoscopic cholecystectomy. The results of the present study are consistent with these findings in that increases in TcPCO$_2$ and PaCO$_2$ were observed 5 min after extubation and these declined postoperatively. These data indicate that patients should be carefully monitored, not only in the operating theatre but also in the recovery room.

There is some debate in the literature as to whether ETCO$_2$ is a reliable predictor of PaCO$_2$.
in patients undergoing laparoscopic cholecystectomy with carbon dioxide insufflation. It has been reported that there is no distinct change in the arterial to end-tidal $\text{Paco}_2$ gradient during laparoscopic cholecystectomy with carbon dioxide insufflation. Similarly, there were no statistically significant differences between $\text{Paco}_2$ and $\text{ETCO}_2$ during carbon dioxide insufflation in another study involving ASA I and II patients undergoing laparoscopic cholecystectomy. Increases in the arterial to end-tidal $\text{Paco}_2$ gradient (approximately 11 mmHg) have, however, been reported in patients with cardiac or pulmonary disease. The $\text{ETCO}_2$ may, therefore, reflect $\text{Paco}_2$, meaning that continuous follow-up of ventilatory sufficiency by capnography during surgery may limit the number of patients experiencing hypercarbia. In a study of women undergoing laparoscopic hysterectomy, it was reported that maintenance of $\text{ETCO}_2$ at a normal, or somewhat lower level than normal, during laparoscopy by increases in the tidal volume, can keep $\text{Paco}_2$ in the normal range. That study concluded that it would be more effective to manage the increased requirement for ventilation by increasing the tidal volume rather than increasing the number of respirations.

In the present study, mean $\text{TcPCO}_2$ increased with increasing duration of insufflation and then began to decline 20 min postoperatively. This was particularly demonstrated in one patient where the duration of surgery was 125 min; the $\text{TcPCO}_2$ of this patient after extubation was 72.3 mmHg decreasing to 42.6 mmHg by 20 min after the operation. Although $\text{TcPCO}_2$ was declining 20 min after operation, it was still significantly higher than preoperative values, suggesting that the time to return to normal levels is prolonged. The present study also showed that $\text{Paco}_2$ was increased in proportion to the duration of insufflations, reaching a peak after extubation. Similarly to the $\text{TcPCO}_2$ data, the raised $\text{Paco}_2$ levels had started to decrease by 20 min after the operation but had still not reached preoperative values. These data are consistent with a study in female patients undergoing elective laparoscopy in which $\text{Paco}_2$ and $\text{ETCO}_2$ increased after carbon dioxide insufflation, although the increase was not reported to be statistically significant in that study. It has been shown that $\text{ETCO}_2$ increases in proportion to $\text{Paco}_2$ but the difference between $\text{Paco}_2$ and $\text{ETCO}_2$ increases over time. In the present study, the difference between $\text{TcPCO}_2$ and $\text{Paco}_2$ was not statistically significant at the majority of time-points, demonstrating that these parameters may be subject to parallel changes during carbon dioxide insufflation or are closely related to each other. These measurements can be obtained with minimal inconvenience to the patient.

In conclusion, the present study demonstrated that $\text{TcPCO}_2$ was a valid and practical measurement in patients with COPD undergoing laparoscopic cholecystectomy. In these patients, $\text{TcPCO}_2$ and $\text{ETCO}_2$ could be used instead of the currently preferred method of arterial blood gas sampling.

**Conflicts of interest**

The authors had no conflicts of interest to declare in relation to this article.
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