

Original Article

Evaluation of low tidal volume with positive end-expiratory pressure application effects on arterial blood gases during laparoscopic surgery

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Abstract

Background: Pneumoperitoneum (PNP) and patient positions required for laparoscopy can induce pathophysiological changes that complicate anesthetic management during laparoscopic procedures. This study investigated whether low tidal volume and positive end-expiratory pressure (PEEP) application can improve ventilatory and oxygenation parameters during laparoscopic surgery.

Methods: A total of 60 patients undergoing laparoscopic surgery were randomized to either the conventional group ($n = 30$, tidal volume = 10 mL/kg, rate = 12/minute, PEEP = 0 cm H₂O) or the low tidal group with PEEP group ($n = 30$, tidal volume = 6 mL/kg, rate = 18/minute, PEEP = 5 cm H₂O) at maintenance of anesthesia. Hemodynamic parameters, peak plateau pressure (Pplat) and arterial blood gases results were recorded before and after PNP.

Results: There was a significant increase in the partial pressure of arterial carbon dioxide (PaCO₂) values after PNP in the conventional group in the reverse Trendelenburg (41.28 mmHg) and Trendelenburg positions (44.80 mmHg; $p = 0.001$), but there was no difference in the low tidal group at any of the positions (36.46 and 38.56, respectively). We saw that PaO₂ values recorded before PNP were significantly higher than the values recorded 1 hour after PNP in the two groups at all positions. No significant difference was seen in peak inspiratory pressure (Ppeak) at the reverse Trendelenburg position before and after PNP between the groups, but there was a significant increase at the Trendelenburg position in both groups (conventional; 21.67 cm H₂O, $p = 0.041$, low tidal; 23.67 cm H₂O, $p = 0.004$). However, Pplat values did not change before and after PNP in the two groups at all positions.

Conclusion: The application of low tidal volume + PEEP + high respiratory rate during laparoscopic surgeries may be considered to improve good results of arterial blood gases.

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Keywords: laparoscopy; pneumoperitoneum; positive end-expiratory pressure

1. Introduction

Laparoscopic procedures often result in multiple post-operative benefits allowing for quicker recovery and shorter hospital stay. These advantages explain the increasing success of laparoscopic surgery, which has been proposed for many surgical procedures. However, pneumoperitoneum (PNP) and the patient positions required for laparoscopy induce pathophysiological

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changes that complicate anesthetic management.¹ PNP is a complex but well-tolerated pathophysiological state characterized by an increase in the intra-abdominal pressure and the partial pressure of carbon dioxide (CO₂); it also significantly affects respiratory mechanics such as intraoperative atelectasis, elevated peak inspiratory pressure (Ppeak) and plateau pressure (Pplat) and decreases dynamic compliance of the respiratory system.^{2–5}

Although no one anesthetic technique has been proven to be clinically superior to other techniques, general anesthesia with controlled ventilation seems to be the safest technique for operative laparoscopy.¹

Lung protective ventilation has evolved over the last several decades and has focused largely on patients suffering from acute respiratory distress syndrome (ARDS) and acute lung injury (ALI). There is clear evidence from animal and human data that mechanical ventilation can induce and exacerbate lung injury, and thus the current standard of care is the use of a lung protective ventilation strategy in patients suffering from ARDS or ALI.^{6,7}

Many researchers have conducted several large randomized trials showing that the use of lower tidal volumes is associated with improved outcomes and a reduction in the incidence of ventilatory induced lung injury.^{8,9} In addition to the reduction of tidal volume, increasing the level of positive end-expiratory pressure (PEEP) is now considered as an integral part of protective ventilation.¹⁰

The data for the use of low tidal volume in patients undergoing lower-risk elective operations is less evident. However, evidence also exists that mechanical ventilation can be injurious to the lungs and other organ systems in patients without ALI or ARDS.¹⁰

In this study, we wanted to compare the effects of low tidal volume with PEEP and conventional ventilation strategy during laparoscopy at the head-up or head-down positions.

2. Methods

This study was approved by the Afyon Kocatepe University Hospital Ethics Committee, and written informed consent was obtained from each patient. We prospectively enrolled into our study 60 patients with American Society of Anesthesiologists (ASA) physical status I–II, whose ages were between 20 and 75 years and who were undergoing laparoscopic procedures such as cholecystectomy, hysterectomy, cystectomy, and surgery for colon cancer. Pregnant women, patients with cardiorespiratory disease and obesity (body mass index > 40 kg/m²), previous lung surgery, or home oxygen therapy were excluded from the study.

Patients were randomized to either the conventional group ($n = 30$) or the low tidal group with PEEP group ($n = 30$) using the sealed envelope system.

Upon arrival in the operating room, patients were monitored with standard anesthetic monitors. A standardized anesthetic technique was used in both groups. Patients were premedicated with 0.1 mg/kg midazolam 1 hour before induction of anesthesia. Thereafter, anesthesia was induced with an infusion of

remifentanyl (0.2 µg/kg/minute for 5 minutes) and a bolus dose of propofol (2–2.5 mg/kg). Intubation was facilitated with 0.6 mg/kg rocuronium. Maintenance of anesthesia was provided by continuous infusion of propofol (3–5 mg/kg/minute) and remifentanyl (0.1–0.2 µg/kg/minute). All patients were ventilated with an S15 Avance anesthetic machine (GE Healthcare, Madison, WI, USA). We divided the patients into two groups according to the ventilatory settings (conventional and low tidal group). Then we adjusted them into four subgroups: (1) conventional group in the Trendelenburg position; (2) conventional group in the reverse Trendelenburg position; (3) low tidal group in the Trendelenburg position; and (4) low tidal group in the reverse Trendelenburg position. In all groups, inspiratory to expiratory time ratio was 1:2 and inspired oxygen fraction (FIO₂) was 0.5 (balanced with air). In the conventional group, ventilatory settings included a rate of 12/minute, tidal volume; 10 mL/kg and a PEEP set at 0 cm H₂O. In the low tidal group with PEEP group, the ventilator settings were adjusted to a rate of 18/minute, tidal volume; 6 mL/kg and a PEEP of 5 cm H₂O. The ventilatory rates were increased as end-tidal CO₂ concentration (ETCO₂) level was >50 mmHg. The magnitude of Ppeak and Pplat was obtained directly from the ventilator and was recorded 10 minutes before PNP (T1) and 1 hour after PNP (T2). Arterial blood gas was analyzed at T1 and T2. All hemodynamic parameters such as heart rate (HR), mean arterial pressure (MAP), peripheral oxygen saturation (SpO₂), and ETCO₂ were also recorded. After surgery was completed, patients were extubated in the operating room.

CO₂ PNP was created with a closed Veress needle technique maintaining a 14 mmHg intra-abdominal pressure. After insufflation, patients were placed in the Trendelenburg or reverse Trendelenburg position according to their type of surgery (cholecystectomy was done at the Trendelenburg position and hysterectomy, cystectomy, and colon cancer were done at the reverse Trendelenburg position) and then laparoscopic procedures were performed by surgeons.

Statistical analyses were performed using the Statistical Package SPSS version 18 (SPSS Inc., Chicago, IL, USA). Data were expressed as mean ± standard deviation (SD) or median. The Mann-Whitney U test was used to compare continuous variables and the Chi-square test was used to compare categorical variables. The Wilcoxon signed rank test was used to compare preoperative and postoperative variables. We used $\alpha = 0.05$ with a power ($1 - \beta$) of 0.9 with regards to the study conducted by Kim et al.¹¹ and we studied 15 patients per four subgroups. A p value <0.05 was considered to indicate a statistically significant difference.

3. Results

A total of 30 patients were included in each group, and all completed the study. Patient characteristics were similar between the groups ($p > 0.05$, Table 1). There were no statistically significant differences between the hemodynamic parameters (MAP, HR) measured before anesthesia induction (before and after PNP) in each group ($p > 0.05$, Table 2). Operation characteristics of each group are shown in Table 3,

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