



## Comparison of Pressure-controlled Inverse Ratio Ventilation versus Pressure-controlled Ventilation in Laparoscopic Cholecystectomy with LMA

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### Authors' contributions

This work was carried out in collaboration between all authors. Author JMH designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author DMH managed the literature searches, analyses of the study performed the spectroscopy analysis and author VS managed the experimental process and author NB identified the species of plant. All authors read and approved the final manuscript.

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### ABSTRACT

**Aims:** In comparison with volume-controlled ventilation (VCV), the pressure controlled ventilation (PCV) improves oxygenation and ventilation. PCV method decreases peak airway pressure in laparoscopic surgery. The aim of this study is comparison of PCIRV with I: E ratio 1.5:1 and PCV with I:E ratio 1:2 in laparoscopic cholecystectomy with LMA.

**Study Design:** Before-after clinical trial study.

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**Place and Duration of Study:** Departments of Anesthesiology, Shahid Sadoughi University of Medical Sciences, Yazd, Iran, between Jul 2014 and Dec 2015.

**Methodology:** Forty patients who were candidate of elective laparoscopic cholecystectomy were selected. Preparation and medication for anesthesia were same for all patients. Anesthesia ventilation was started by VCV mode, co2 insufflation was done and ventilation continued by PCV mode. Pulmonary and cardiac parameters were examined at baseline. After 20 min results were recorded and then I: E ratio was changed to 1.5:1 and PEEP of 5 cm of H<sub>2</sub>O continued. Results were recorded after 10 min of PCIRV.

**Results:** The mean age of patients was 41±11.8 years old. About of participants 25% were male and the mean of BMI was 25.6±2.57.

The Peak pressure were higher in PCV (p-value: 0.001). Plateau pressure was higher during PCIRV (p-value: 0.762). Our results revealed Etco<sub>2</sub> significantly increased in PCV. (p-value: 0.023). Airway pressure significantly increased in PCIRV (p-value: 0.001). Tidal volume significantly increased during PCIRV (p-value: 0.001) too. Also in PCIRV mode spo<sub>2</sub>, heart rate, compliance and PAW were significantly increased. According to our findings there was a significant association between BMI and changes in plateau pressure (p-value: 0.01) and Etco<sub>2</sub> (p-value: 0.03) in PCVIR method.

**Conclusion:** Our study suggests PCIRV as an effective mode of ventilation that could be used in laparoscopic surgery especially in moderately obese patients.

*Keywords: Laparoscopic cholecystectomy; ventilation; laryngeal mask.*

## 1. INTRODUCTION

Laparoscopic surgery is a most common method which is used for cholecystectomy [1-3]. But one of the disadvantages of this method (laparoscopic cholecystectomy) is increasing peak airway pressure and reducing functional residual capacity. Pneumoperitoneum induction during laparoscopic surgery will increase intra-abdominal pressure and cause abdominal cavity enlargement [4,5]. Secondary to diaphragm elevation and abdominal cavity expansion, the intra-thoracic pressure increases and the lungs are restricted. This pathophysiological mechanism will decrease pulmonary dynamic compliance and increases peak airway pressure which are associated with pulmonary barotrauma [6]. Therefore the anesthesiologists use pressure controlled ventilation (PCV) which can change the respiratory rate and tidal volume. Laryngeal mask airway (LMA) is generally used which is a safe and effective device in laparoscopic surgery [7-10]. It is suggested that PCV with LMA is more efficient than VCV [11,12]. Pressure-controlled inverse ratio ventilation (PCIRV) is a proper alternative of VCV for adult surgery as well as acute respiratory distress syndrome patients, postoperative cardiac surgeries and intensive care unit [13-16]. Ventilation, alveolar gas distribution and Tidal volume delivery in (PCIRV) mode is improved in comparison with VCV. Also decelerating inspiratory flow is accentuated in (PCIRV) method. (PCIRV) can be applied during the anesthesia in patients with high peak. Some of studies suggested application of (PCIRV) can

be an effective mode of ventilation in major gynecological laparoscopic surgery using LMA [12,17]. It is associated with the rise in PAW, oxygen saturation and dynamic lung compliance, which are indicators of better alveolar ventilation. This study was designed to investigate whether altering the I: E ratio to 1.5:1 in PCIRV could reduce P<sub>peak</sub> or the plateau pressure, improve oxygenation and other pulmonary and cardiac parameters in patients undergoing laparoscopic cholecystectomy with LMA.

## 2. MATERIALS AND METHODS

After ethics committee approval of Shahid Sadoughi University of medical sciences, Yazd, Iran, 40 patients 25 - 65 years old undergoing elective laparoscopic cholecystectomy with ASA (American society of anesthesiologists) class I-III, were included in this double blinded clinical trial study. All of the patients were visited by an anesthesiologist. Past history, physical examination, BMI, laboratory tests and imaging modalities results were recorded by an anesthesia resident. Written informed consent obtained from all patients. The patients with history of Gastro-esophageal reflux, allergy to anesthesia medication or suspected difficult intubation were excluded by an anesthesia resident. Each patients received Ranitidine 150 mg, clonidine 100 mg and metoclopramide 10 mg orally as preoperative medication one hour before the surgery by a trained technician. Anesthetic protocol was included pre-oxygenation, then IV injection of midazolam

1 mg, fentanyl 3 µg/kg and Propofol 2-2.5 mg/kg for all of the patients. Neuromuscular blockade was achieved with atracurium 0.6 mg/kg IV stat and maintainance with 0.12 mg/kg IV. The proper LMA was selected according to the body weight. Size 4 for patients with body weight of 50-70 kg (10 cases), and Size 5 for patients with body weight of 70-100 kg (30 cases). The cuff was inflated with air until effective seal was obtained to the maximum 30 cc when there was no audible or palpable leak. VCV was started after reaching the desired intra-abdominal pressure (15 mm of Hg) with patient in Trendelenburg position. Tidal volume was regularized on 8 ml/kg and respiratory rate was regularized on 8-10/min. The end-tidal carbon dioxide (Etco<sub>2</sub>) was adjusted between 34-38 mmHg. The spirometry, non-invasive blood pressure, pulse oximetry, end tidal carbon dioxide, ECG and gas monitoring were done and recorded. VCV was changed to PCV after pneumopritonem with positive end expiratory pressure (PEEP) of 5 cm of H<sub>2</sub>O and I:E ratio 1:2. After 20 min cardiopulmonary variables including (peak and plateau pressures, tidal volume, Etco<sub>2</sub>, dynamic compliance, Heart rate, Mean arterial pressure, paw, end tidal volume and spo<sub>2</sub>) were recorded and then I: E ratio was changed to 1.5:1 and PEEP of 5 cm of H<sub>2</sub>O continued. Cardiopulmonary variables were recorded after 10 min of PCIRV again by a trained anesthesia technician blinded to the study protocol.

So recordings were noted as per the following schedule:

- a) Baseline VCV, prior to peritoneal insufflation with carbon dioxide.
- b) On VCV with PEEP of 5 cm of H<sub>2</sub>O after reaching the desired intra-abdominal pressure (15 mm of Hg) with patient in Trendelenburg position.
- c) After 20 min of PCV with I: E = 1:2
- d) 10 min after PCIRV with I: E = 1.5: 1

Ppeak, plateau pressure (Pplat), mean airway pressure (Pmean), PEEP (auto-PEEP), and dynamic compliance of the respiratory system recorded by an Anesthesia device (Fabius plus, Drager company, Germany) and Heart rate, Mean arterial pressure, paw, end tidal volume and spo<sub>2</sub> recorded by a bedside monitoring (Alborz B5, Iran).

Any presence of oropharyngeal leak, hypotension, bradycardia, auto-PEEP, Hemodynamic, spirometry, EtCO<sub>2</sub>, and pulse oximeter recordings were noted.

The surgeon was blinded to the anesthesia protocol.

Statistical analysis was done using paired t-test and results were obtained at 95% confidence limit (SPSS version 20.0). Significance was defined at  $p \leq 0.05$ . Data were presented as mean (SD). The main variable in the study, the mean airway pressure, was having a standard deviation of 1.2 from the pilot study done on 40 patients. A priori power analysis using two-sided analysis with an error of 0.05 and a power of 0.8 showed that 40 patients were needed for the study.

### 3. RESULTS

All of the 40 study participants were adult. The mean age of patients was  $41 \pm 11.8$  years old.

About of participants 25% were male and the mean of BMI was  $21.36 \pm 2.54$ .

The Peak pressure was higher in PCV (p-value: 0.001). Plateau pressure was higher during PCIRV (p-value: 0.762). Our results revealed Etco<sub>2</sub> significantly increased in PCV. (p-value: 0.023). Airway pressure significantly increased in PCIRV (p-value: 0.001). Tidal volume significantly increased during PCIRV (p-value: 0.001) too. Also in PCIRV mode spo<sub>2</sub>, heart rate, compliance and PAW were significantly increased. The comparison between PCV and PCIRV is shown in Table 1. According to our findings there was a significant association between BMI and changes in plateau pressure (p-value: 0.01) and Etco<sub>2</sub> (p-value: 0.03) in PCVIR method.

### 4. DISCUSSION

In this before-after clinical trial study we compared the cardiopulmonary variables in PCIRV mode with I:E ratio 1.5:1 and PCV mode with I:E ratio 1:2 in patients undergoing laparoscopic cholecystectomy with LMA. The Peak pressure was higher in PCV. Plateau pressure was higher during PCIRV. Our results revealed Etco<sub>2</sub> significantly increased in PCV. Airway pressure significantly increased in PCIRV. Tidal volume significantly increased during PCIRV too. Also in PCIRV mode, spo<sub>2</sub>, heart rate, compliance and PAW were significantly increased. According to our findings there was a significant association between BMI and changes in plateau pressure and Etco<sub>2</sub> in PCVIR method.

**Table 1. The mean cardiopulmonary variable changes between PCV and PCIRV method**

Variable	PCV	PCIRV	p-value
Peak pressure (cmH2o)	17.97±2.49	17.08±2.64	0.001
Plateau pressure (cmH2o)	15.97±2.78	16.03±2.90	0.762
Tidal volume (ml)	591.94±41.25	540.69±47.07	0.001
Dynamic compliance (ml/cmH2o)	42.69±6.07	44.67±7.32	0.007
Etco2 (mmHg)	35.28±3.87	34.33±3.85	0.023
Heart rate (Bpm)	83.58±10.98	87.14±15.42	0.006
Mean arterial pressure (mmHg)	88.86±10.65	88.61±8.68	0.886
Paw (cmH2o)	33.16±4.13	53.25±7.93	0.001
End tidal volume (ml)	542.5±40.86	593.75±47.74	0.001
Spo2 (percent)	97.58±11.28	97.92±10.97	0.003

Laparoscopy is associated with increases peak airway pressure (Ppeak) and high end-tidal carbon dioxide tension (PETCO2) especially in obese patients [18,19].

Laryngeal mask airway (LMA) reduces intubation and extubation response, gives better oxygen saturations at extubation, and reduces postoperative morbidity and analgesia requirement [20]. Use of pressure-controlled ventilation (PCV) with LMA has proved to be beneficial in adult as well as pediatric surgeries. It reduces peak airway pressure and delivers a better tidal volume at comparable airway pressures [11,21]. The improvement in ventilation during PCV is thought to be due to altered flow pattern that improves alveolar gas distribution and not merely due to reduction of air leaks. Inverse ratio ventilation (IRV) has been extensively used in intensive care units, postoperative cardiac surgeries [13] and there are also reports of it being used in lower abdominal surgeries. Longer inspiratory times improve the gas flow to the alveoli of slow time constants, thereby improving oxygenation in Acute Respiratory Distress Syndrome patients. Increase in the mean airway pressure, a typical feature of IRV that recruits collapsed alveoli, could thus improve ventilation during laparoscopy [22].

PCIVR can improve cardiopulmonary response during laparoscopic surgery [17]. Our findings revealed lower peak pressure in the PCIRV mode that was possibly due to slowing inspiratory flow and prolonging inspiratory time of PCIRV. In this study tidal volume was significantly increased in PCIRV comparing with PCV. Increasing in tidal volume is due to slowing flow of PCV associated with inverse I:E ratio. Also peak pressure in PCIRV is lower than PCV. Higher spo2 in PCIRV is due to increase PAW and decrease airway resistance [12,17,23].

Although increased I:E ratio may cause auto-PEEP and barotraumas, moderately reverse I:E ratio (1.5:1) will improve PAW and oxygenation [23]. Therefore PCIRV restricted auto-PEEP. Also the heart rate was increased in PCVIR method in our study similar to previous studies. According to our findings there was a significant association between BMI and changes in plateau pressure and Etco2 in PCVIR method, which suggested that the patients with greater BMI will derive benefits of PCVIR in compare with PCV.

CUI Chao et al. [24] in 2015 investigated the effect of pressure-controlled inverse ratio ventilation using laryngeal mask airway in gynecological laparoscopy. Thirty patients between 18 and 60 years, American Society of Anesthesiologists class 1-3, undergoing elective major gynecological laparoscopy were included in the study. Pressure-controlled ventilation (PCV) was initiated with tidal volume 8 mL/kg, inspiratory–expiratory (I : E) ratio was kept 1 : 2, with positive end expiratory pressure (PEEP) of 5 cm H2O. After 15 min of pneumoperitoneum readings were recorded. I : E ratio was changed to 1.5 : 1 on the (PCIRV) mode and PEEP of 5 cm H2O continued. Readings were taken after 15 min of PCIRV. According to their results PCIRV with I:E ratio 1.5: 1 can be an effective mode of ventilation in major gynecological laparoscopy using LMA.

W. P. Zhang et al. [25] in 2016 investigated whether volume controlled inverse ratio ventilation (IRV) with inspiratory to expiratory (I:E) ratio of 2:1 could reduce Ppeak or the plateau pressure (Pplat), improve oxygenation, and alleviate lung injury in patients with normal lungs. In their study Sixty obese patients undergoing gynecological laparoscopy were enrolled. After tracheal intubation, the patients were randomly divided into the IRV group (n = 30) and control group (n = 30). They were

ventilated with an actual tidal volume of 8 mL/kg, respiratory rate of 12 breaths/min, zero positive end-expiratory pressure and I:E of 1:2 or 2:1. Arterial blood samples, hemodynamic parameters and respiratory mechanics were recorded before and during pneumoperitoneum. According to their results volume-controlled IRV not only reduces Ppeak, Pplat but also increases mean airway pressure, and improves oxygenation and dynamic compliance of respiratory system in obese patients undergoing gynecologic laparoscopy without adverse respiratory and hemodynamic effects. It is superior to conventional ratio ventilation in terms of oxygenation, respiratory mechanics and inflammatory cytokine in obese patients undergoing gynecologic laparoscopy.

## 5. LIMITATIONS

Short time for PCIRV method duration, small sample size, non invasive hemodynamic parameters monitoring and no arterial blood gas sampling should be considered as our study limitations.

## 6. CONCLUSION

As a conclusion, among the ventilation method which is used in laparoscopic surgery, PCIRV is a beneficial method. This method improves dynamic lung compliance and alveolar ventilation. PCVIR is also associated with increased PAW and oxygen saturation. Our study suggests PCIRV as an effective mode of ventilation that could be used in laparoscopic surgery especially in moderately obese patients.

## ETHICAL APPROVAL

This study was approved by the ethics committee of the Shahid Sadoughi University of medical sciences, Yazd, Iran. Written informed consent obtained from all patients.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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