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Comparison of Respiratory Mechanics - Volume Controlled Ventilation Versus Pressure Controlled Ventilation using Proseal Laryngeal Mask Airway during Laparoscopic Cholecystectomy: A Cross-over Study

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Abstract

Background and aim: Pressure Controlled Ventilation (PCV) is claimed to be superior to Volume Controlled Ventilation (VCV) but with insufficient evidence. The aim was to compare the respiratory mechanics in VCV and PCV with Proseal Laryngeal Mask Airway (PLMA) in patients undergoing laparoscopic cholecystectomy. **Methods and Materials**: Study was conducted involving 50 ASA I and II patients aged 20-50 years undergoing laparoscopic cholecystectomy in this open label study. Patients were randomly allocated into group V and group P. Induction and maintenance of anaesthesia was uniform in both groups. All patients received Volume Controlled Ventilation till pneumoperitoneum, following which patients in group V received volume controlled ventilation for 20 minutes and switched over to PCV and vice versa for group P (PCV). Ventilator parameters for PCV and VCV were uniformly set initially irrespective of group allocation and adjusted later to maintain $PaCO_2$ 35 – 45 mm of Hg and SpO_2 > 95%. Baseline hemodynamic parameters and respiratory parameters like peak and mean airway pressures, compliance were recorded during each mode of ventilation for 20 minutes. Data analyzed using IBM SPSS software version 20, Student T-test applied, P value < 0.05 considered significant. **Results**: Demographic data was comparable between two study groups. Peak airway Pressures (Ppeak) were 24.2 ± 2.38 cm of H_20 during VCV and 22.46 ± 2.07 cm of H_20 during PCV respectively (P value 0.019). Compliance was found to be 20.58 ± 5.1 cm of H_20 during VCV and 21.56 ± 5.1 cm of H_20 during PCV respectively (P-value 0.016). Airway resistance and expired tidal volumes were comparable. None of patients had desaturation or hypercarbia. **Conclusion**: Pressure controlled ventilation is better than volume controlled ventilation in terms of lower airway pressures and increased dynamic compliance.

Keywords: Laparoscopy, Pressure Control Ventilation, Proseal LMA, Volume Control Ventilation

Introduction

General anaesthesia with endotracheal intubation is the standard practice in management of patients during laparoscopic surgeries[1]. Peak air way pressure (Ppeak) increases secondary to rise in intra-abdominal pressure after pneumoperitoneum. Proseal Laryngeal Mask Airway (PLMA), a Supraglottic Airway Device (SAD) with a gastric drain tube has been used widely in paediatric[2], and in adult patients undergoing laparoscopic cholecystectomy[3]. Most of the studies comparing supraglottic airway devices have used volume controlled ventilation as a mode of ventilation[4]. Pressure controlled ventilation has been shown to provide better oxygenation and ventilation compared to volume controlled ventilation at lower peak airway pressure[5]. Literature search revealed very few studies

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comparing volume controlled versus pressure controlled ventilation with Proseal LMA. Our aim was to assess the effects of two modes of ventilation on respiratory mechanics using Proseal laryngeal mask airway with respect to peak airway pressures, mean airway pressure, compliance and airway resistance in patients undergoing laparoscopic cholecystectomy. Changes in peak airway pressure was the primary outcome measure and changes in compliance, airway resistance, mean airway pressure and haemodynamic parameters were secondary outcome measures.

Methods

This prospective randomized open label study was approved by institution ethical committee. American Society of Anaesthesiologists (ASA) class I and II patients aged between 20-50 years, undergoing laparoscopic cholecystectomy were included. Exclusion criteria exercised were patients with BMI >30 kg/m^2, anticipated difficult airway, respiratory, cardiovascular, neurological, endocrine disorders, and patients on anti-hypertensive, alpha 2 agonists and psychiatric medications. Patients with history of upper respiratory tract infections, hepatic and renal disorders were also excluded from study. We hypothesized that peak airway pressures required to achieve desired tidal volume may be lesser with pressure controlled ventilation compared to volume controlled ventilation[5]. Sample size was based on a pilot study, where we noted an average peak airway pressure of 23 ± 2.4 cm of H_20 with VCV. To detect a minimum of 2 cm of H_20 (10%) difference in the peak airway pressures between two modes of ventilation, assuming a standard deviation of 2.5 and normal distribution of values in both groups, a minimum of 25 patients would be required in each group to attain a power of 80% at an alpha error of 0.05. We included 28 patients in each group to compensate for exclusions. Patients were randomly allocated to two groups using computer generated randomization sequence (www.randomization.com) method into GROUP V- Volume controlled ventilation and GROUP P- Pressure controlled ventilation. To avoid allocation, bias the randomized numbers were placed in an opaque sealed envelope.

Pre-anaesthetic evaluation was done and the protocol was explained to patients the previous day. Relevant laboratory investigations including haemoglobin level were carried out for all patients, as per institutional protocol. Informed written consent was obtained. Ideal body weight was calculated for all patients. All patients were kept fasting as per institutional protocol.

On arrival of the patient to the operating room, electrocardiogram (HR), non-invasive blood pressure (NIBP), peripheral oxygen saturation (SpO_2), entropy, nerve stimulator (Train of four) monitors were connected. Baseline hemodynamic and SpO_2 values was recorded.

Pre-medication was done as per routine institutional protocol. All patients were induced with Inj. Propofol 1% until response entropy value reached ≤50. Appropriately sized Proseal LMA device (based on body weight ranges) was prepared for insertion with cuff deflated partially and its dorsal surface lubricated with a water soluble jelly. Proseal LMA insertion facilitated by Inj.Vecuronium 0.1 mg/kg. Proseal LMA was inserted as per recommendations, cuff inflated upto a pressure of 60 cm of H_2O. Proper placement of proseal LMA was confirmed by absence of audible leak from oral cavity, capnography and absence of leak ensured by negative gel displacement test. Inability to properly place Proseal LMA even after a maximum of 2 attempts was considered as failure and such cases were managed with endotracheal intubation, also cases with peri-cuff leak i.e., > 5% difference in inspired and expired tidal volume, patients in whom laparoscopy was converted to open surgery were also excluded from study.

Pneumoperitoneum was created with carbon dioxide to maintain intra-abdominal pressure (IAP) at 12-14 mmHg. Patients were maintained with O_2/air mixture and Isoflurane titrated to maintain response entropy between 40-60. Neuromuscular blockade was monitored using Train of Four (TOF) and Inj.Vecuronium 0.03 mg/kg top-up's to maintain TOF count <2.

All patients received Volume Controlled Ventilation (VCV) from ventilator (S/5 Avance GE™ health care Datex Ohmeda workstation) for the initial period till creation of pneumoperitoneum, the tidal volume set was 7 ml/kg ideal body weight, respiratory rate of 14 breaths/min, inspiratory: expiratory ratio of 1:2 and PEEP of 5 cm of H_2O. Once pneumoperitoneum was achieved envelope was opened to decide whether patient would receive volume controlled ventilation (group V) or pressure controlled ventilation (group P) as per randomization sequence.

Initial ventilator settings in group V was tidal volume of 7 ml/kg (ideal body weight) and group P, a peak inspiratory pressure (P_{Insp}) of 15 cm of H_20, after pneumoperitoneum. Respiratory rate of 14/min, inspiratory to expiratory ratio (I:E) of 1:2 and positive end expiratory pressure (PEEP) of 5 cm of H_20 were common during initial settings amongst both groups. Later intra-operatively tidal volume was adjusted by 25 ml in group V and peak inspiratory pressure by 2 cm of H_20 in group P increments or decrements as required, to maintain $EtCO_2$ between 35-45 mmHg and SpO_2 >95 %.

Once started with initial mode of VCV or PCV, patients were ventilated for 20 mins, following which the mode was switched to alternate mode (VCV to PCV in Group V and PCV to VCV in group P) and ventilated till the end of surgery. Respiratory mechanics and hemodynamic parameters were recorded every 5 mins throughout the intraoperative period.

At the end of surgery, all patients received Inj. Ondansetron 0.1 mg/kg for prevention of post operative nausea and vomiting. Muscle relaxation was reversed with Inj.Neostigmine 2.5 mg/kg and Glycopyrrolate 0.01 mg/ kg intravenous and airway device removed when patient was awake and spontaneously breathing. Patients were monitored in Post Anaesthesia Care Unit (PACU).

Occurrence of hypoxia, hypercarbia, blood staining of Proseal LMA, sore throat or any other respiratory events if any was recorded.

Data was entered and tabulated in Microsoft excel sheet and analyzed using IBM SPSS version 20 software. The initial 20 min values of each respiratory parameter during each mode of ventilation after creation of pneumoperitoneum was taken for analysis. Continuous variables are expressed as mean ± SD whereas categorical variables are expressed as numbers and frequencies. Shapiro-Wilk test was applied to test normality of continuous variables. For the purpose of statistical analysis, the parameters during pressure controlled and volume controlled ventilation were merged from both groups respectively. Independent sample t-test was used for normally distributed values and Wilcoxon signed rank test for values showing skewed distribution. Chi square test was used for comparison of categorical data. A P-value of ≤ 0.05 was considered significant.

Results

A total of 60 patients were screened, out of which 56 met the inclusion criteria. 3 patients in group V and 1 patient in group P were excluded due to change of surgery from laparoscopic procedure to open cholecystectomy. 52 patients were included for final analysis. Both the groups were comparable with respect to age, gender distribution and body mass index (Table 1).

Upon initiation of pneumoperitoneum and changeover of modes of ventilation, at the end of 20^{th} minute, it was found that average peak airway pressures were lower with PCV - 22.19 ± 2.14 cm of H_20 compared to VCV- 24.12 ± 2.44 cm of H_20 respectively ($p < 0.001$) (Table 2, Figure 1).

Average compliance was found to be higher with PCV compared to VCV throughout the period of pneumoperitoneum i.e., 20.61 ± 5.18 ml/cm of H_20 (group V) and 21.75 ± 5.19 ml/cm of H_20 (group P) respectively. P value was <0.001 which was statistically significant (Table 2, Figure 2).

Mean airway pressures were found to be similar with both modes of ventilation i.e., VCV- 9.35 ± 1.15 cm of H_20 and PCV - 9.38 ± 1.27 cm of H_20. (p- value 0.78) (Table 2, Figure 3a).

Average airway resistance was comparable between the modes of ventilation, no intragroup variability seen in both groups.

Hemodynamic parameters like, heart rate, systolic blood pressure, diastolic blood pressure and mean arterial blood pressure were comparable between both groups (Table 2, Figure 3b).

All other respiratory parameters were comparable between two study groups (Table 2). One patient had hoarseness of voice, and no other complications were noted in any other patient.

Discussion

During laparoscopy an elevated intra-abdominal pressure and abdominal expansion shifts the diaphragm upwards resulting in restriction of chest wall movement and increased intra-thoracic pressure. This leads to a significant decrease in pulmonary dynamic compliance and an increase in the peak airway pressure (Ppeak)[6,7]. PCV has been proposed as an alternative to VCV for intensive care unit patients with Adult respiratory distress syndrome[5]

Table 1. Demographic parameters

DEMOGRAPHIC DATA	Group V (n=26) Mean ± SD	Group P (n=26) Mean ± SD
AGE(years)	38.11 ± 6.20	30.38 ± 8.18
BMI(kg/M²)	25.98±3.42	27.37±2.10
Sex distribution(M:F)	5:11 (M:F)	4:11 (M:F)

The parameters of respiratory mechanics and hemodynamics are tabulated and represented in Table 2.

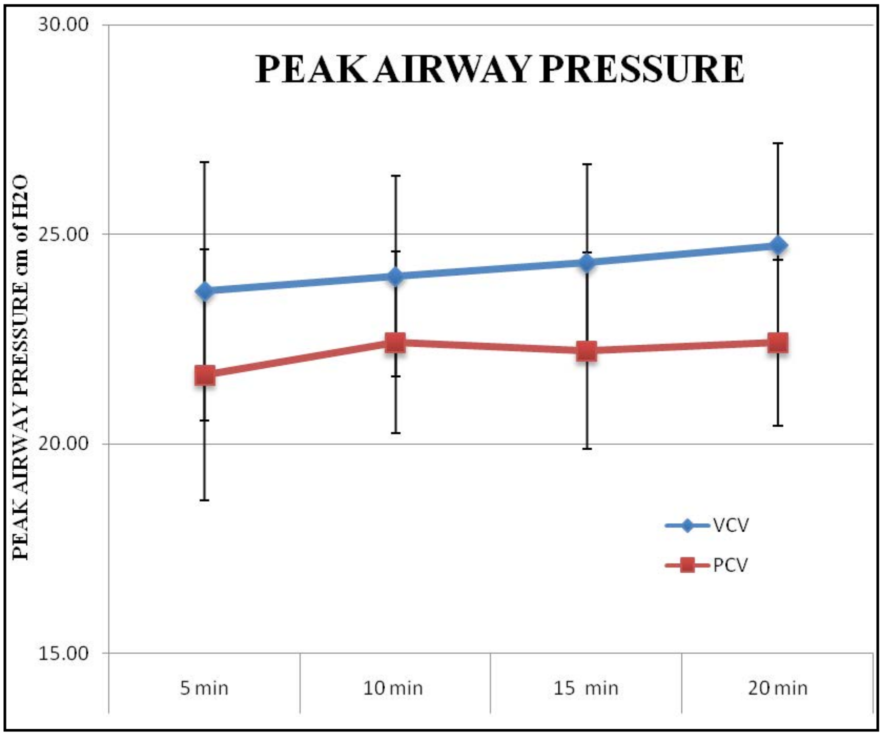

Figure 1. Comparison of peak airway pressures between the groups.

Table 2.

PARAMETER		VCV	PCV	P- value
PEAK AIRWAY PRESSURE(cm of H_20)	Mean ± SD	24.12 ± 2.44	22.19 ± 2.14	0.000
	Confidence Interval (95%)	23.21-25.03	21.39-22.99	
COMPLIANCE (ml/cm of H_20)	Mean ± SD	20.61 ± 5.18	21.75 ± 5.19	0.000*
	Confidence Interval (95%)	18.71-22.51	19.85-23.66	
	Median	19.00	20.5	
	Range	19.75	19	
AIRWAY RESISTANCE(cm of H_20/L/Sec)	Mean ± SD	10.17 ± 3.11	10.76 ± 5.15	0.857*
	Confidence Interval (95%)	9.01 – 11.33	8.84-12.69	
	Median	9.87	9.75	
	Range	18.75	25.25	
MEAN AIRWAY PRESSURE(cm of H_20)	Mean ± SD	9.35 ± 1.15	9.38 ± 1.27	0.78
	Confidence Interval (95%)	8.92-9.79	8.90-9.85	
INSPIRED TIDAL VOLUME(ml)	Mean ± SD	413.49 ± 54.85	423.90 ± 52.45	0.160
	Confidence Interval (95%)	393-433.97	401-443.48	
EXPIRED TIDAL VOLUME(ml)	Mean ± SD	390.36 ± 50.80	389.39 ± 50.47	0.71
	Confidence Interval (95%)	371.39-409.25	370.55-408.23	
HEART RATE (Beats/min)	Mean ± SD	88.32 ± 12.4	88.33 ± 11.68	0.94
	Confidence Interval (95%)	83.69-92.95	83.97-92.69	
MEAN ARTERIAL PRESSURE (mm of Hg)	Mean ± SD	96.95 ± 12.38	99.23 ± 11.06	0.29
	Confidence Interval (95%)	92.32-101.57	95.10-103.36	
SYSTOLIC BLOOD PRESSURE (mm Hg)	Mean ± SD	131.30 ± 18.11	134.04 ± 19.08	0.36
	Confidence Interval (95%)	124.53-138.06	126.91-141.16	

DIASTOLIC BLOOD PRESSURE (mm Hg)	Mean ± SD	74.49 ± 11.04	81.31 ± 10.19	0.42
	Confidence Interval (95%)	75.36-83.61	77.50-85.12	
END TIDAL CARBON DIOXIDE($EtCO_2$)	Mean ± SD	35.57 ± 3.16	35.34 ± 3.10	0.614
	Confidence Interval (95%)	34.5-36.64	34.18-36.50	
	Median	36	35.75	
	Range	13	12.75	
END TIDAL ISOFLURANE (Et ISO)	Mean ± SD	0.66 ± 0.14	0.66 ± 0.15	0.91
	Confidence Interval (95%)	0.6-0.71	0.6-0.711	
MINIMUM ALVEOLAR CONCENTRATION (MAC)	Mean ± SD	0.91 ± 0.07	0.92 ± 0.08	0.33
	Confidence Interval (95%)	0.88-0.94	0.89-0.95	
RESPONSE ENTROPY	Mean ± SD	52.12 ± 3.86	50.49 ± 3.54	0.08
	Confidence Interval (95%)	50.70-53.73	49.68-52.29	

* - Wilcoxon signed rank test

and for obese patients to achieve adequate oxygenation and normocapnia[8,9]. PCV delivers the tidal volume faster than does VCV and they have different gas distributions and a high and decelerating inspiratory flow. The decelerating inspiratory flow used in PCV generates higher instantaneous flow peaks and may allow a better alveolar recruitment. These characteristics of PCV tend to compensate for any potential reduction in ventilation caused by a pressure limitation[10]. PCV improves oxygenation without any side-effects.

Our study demonstrated that there was decrease in peak airway pressure with PCV compared to VCV with use of proseal LMA as airway conduit in patients undergoing laparoscopic cholecystectomy. Though the dynamic compliance was found to higher with PCV compared to VCV, our study was not adequately powered to support

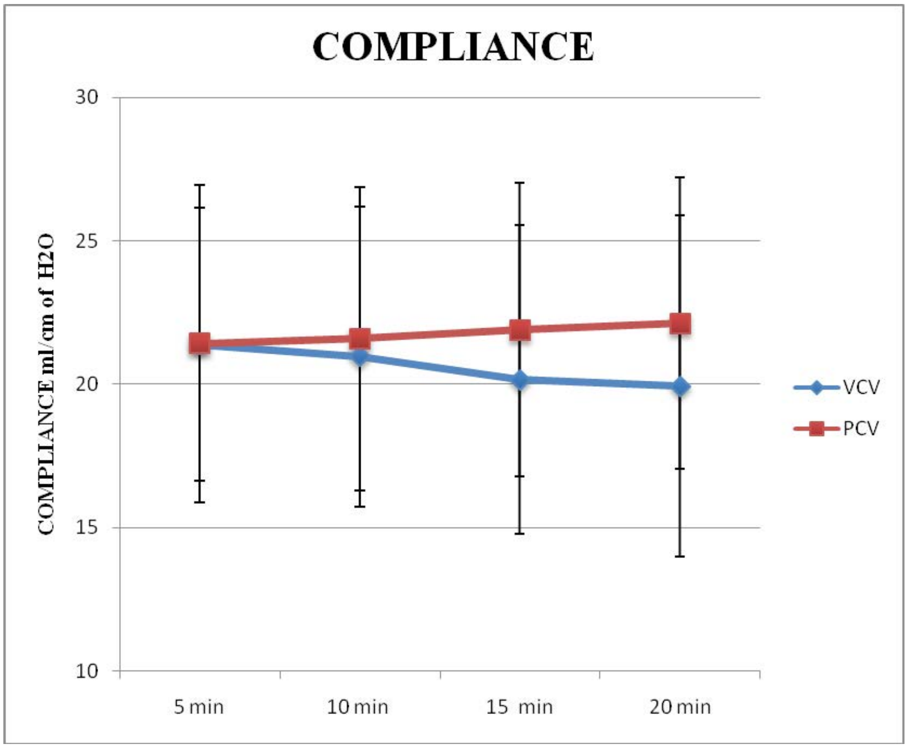

Figure 2. Comparison of compliance between the groups.

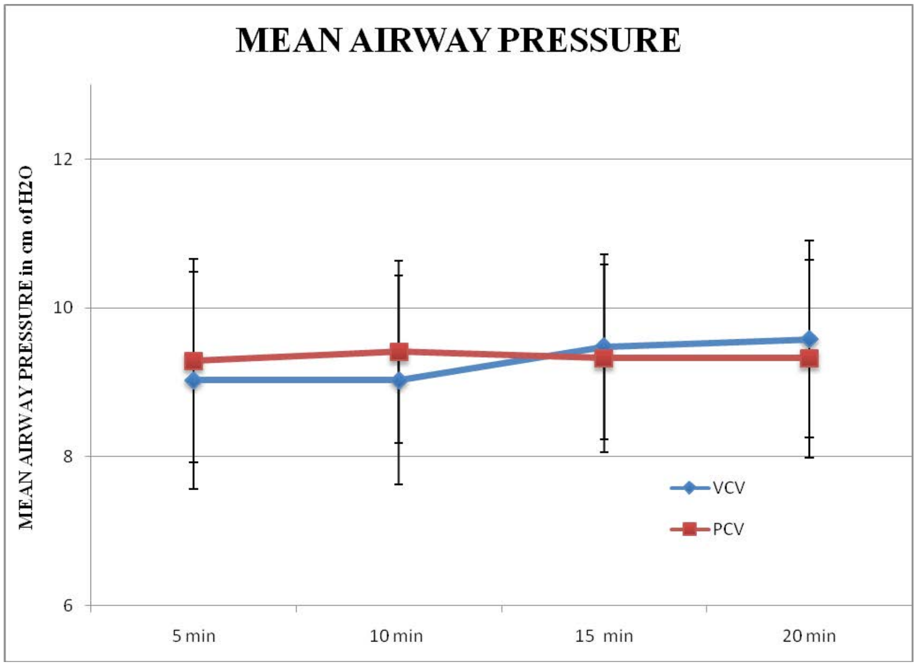

Figure 3a. Comparison of mean airway pressure.

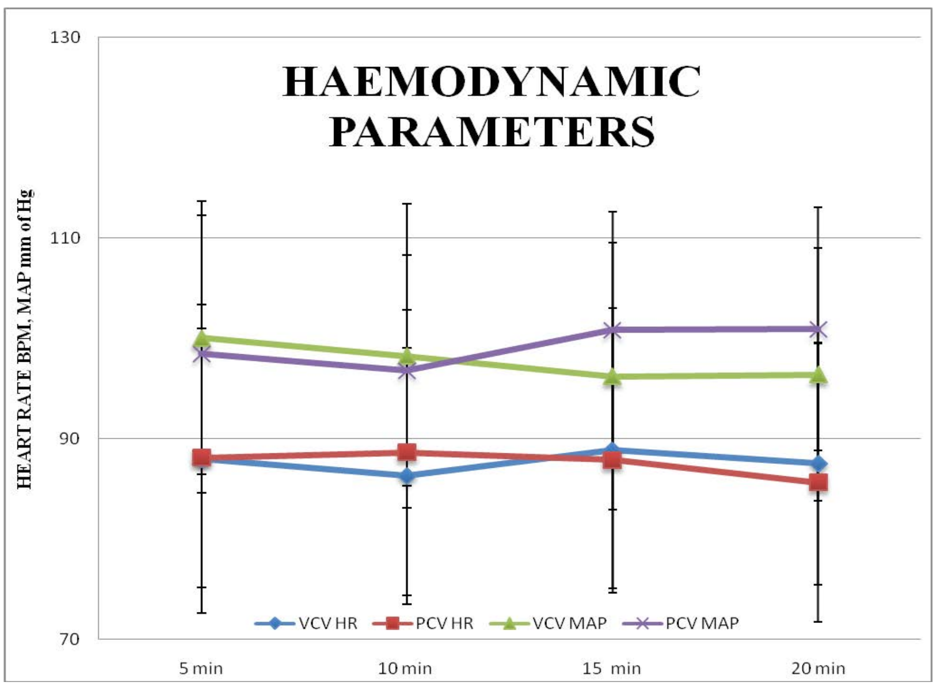

Figure 3b. Comparison of heart rate and mean arterial pressure.

this result. Use of Proseal Laryngeal mask airway was not associated with any significant changes in hemodynamics during both modes of ventilation. We tried to eliminate patient factors, and observer bias by doing a crossover of ventilation methods.

Earlier studies have shown that PLMA is associated with higher oropharyngeal leak airway pressure and can be used successfully in patients undergoing laparoscopic cholecystectomy[11] and another meta-analysis has shown that LMA with gastric drain (PLMA) is associated with lower incidences of regurgitation and aspiration[12].

Proseal LMA was found to provide higher oropharyngeal leak pressures and compliance and lower peak airway pressures[3,13]. Further, addition of Positive End Expiratory Pressure (PEEP) of 5 cm of H_20 maintained better oxygenation compared to PCV without PEEP[14]. PEEP was used with both modes of ventilation in our study.

Various authors have compared two modes of ventilation (VCV and PCV) in patients undergoing laparoscopic surgeries using endotracheal tube as airway conduit in normal as well as obese patients. It was observed that peak airway pressures were lower, and dynamic compliance was higher in PCV group before and 30 minutes after pneumoperitoneum[15–17]. One of the authors also observed that mean airway pressures were higher in PCV group compared to VCV group[15].

Few authors have observed higher average peak airway pressures with VCV compared to PCV in patients undergoing gynaecological laparoscopies under general anaesthesia with LMA[18,19]. Whereas one study using I gel as airway conduit during general anaesthesia in laparoscopic cholecystectomy reported higher compliance with PCV and higher airway pressures and resistance with VCV, other study did not find any significant difference between the modes[20,21].

Wang JP[22] et al in their meta-analysis comparing pressure controlled versus volume controlled ventilation in laparoscopic surgeries observed that irrespective of airway device used, there were no significant differences in heart rate and mean arterial pressure in patients receiving either PCV or VCV.

PCV has been found to consistently be associated with higher PaO_2 in various studies. pH, PaO_2, SaO_2 and PaO_2/FIO_2 were higher in pressure controlled ventilation compared to volume controlled ventilation, in one study, where as $PaCO_2$ has been unaffected in another study[16,20,23].

Few authors have not observed significant difference in oxygenation between two modes[15,22].

This study has limitations, we chose the type of surgery lasting for short duration (40–60 mins), studies with effects of ventilation strategies on prolonged laparoscopic surgeries needs to be evaluated. Also, measurement of lower oesophageal pressure would have helped us to see if the airway pressures had any impact on lower oesphageal sphincter opening and risk of aspiration. Future studies involving assessment of arterial blood gas analysis and bio markers of lung injury may throw more light on the impact of these ventilator strategies on lung protection.

Conclusion

Pressure controlled ventilation is associated with lower peak airway pressures (Ppeak) compared to volume controlled ventilation using Proseal LMA in patients undergoing laparoscopic cholecystectomy.

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