Original research article

PRESSURE CONTROLLED VENTILATION (PCV) VERSUS VOLUME-CONTROLLED VENTILATION (VCV) IN PATIENTS UNDERGOING ELECTIVE LAPAROSCOPIC CHOLECYSTECTOMY: HEMODYNAMIC CHANGES

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Abstract

Pressure controlled ventilation (PCV) is an alternate mode of ventilation which utilizes a decelerating flow and constant pressure. Ventilator parameters are automatically changed with each patient breath, to offer the target tidal volume without increasing airway pressures. All the patients were examined during the pre-operative visit, a day before surgery. Routine blood investigations including complete haemogram, renal function test, blood sugar, chest X-ray and electrocardiogram (ECG) was carried out and recorded. They were kept nil orally 8 hours before surgery and were pre-medicated with alprazolam 0.5 mg per oral (PO), the night before surgery and ranitidine 150 mg and ondansetron 2 mg PO on the morning of surgery. The mean (SD) of heart rate in the VCV group are 71.3 (5.1), 72.1 (4.6) and 73.4 (4.5) at T1, T2 and T3 respectively. In the PCV group are 68.8 (3.0), 71.7 (3.1) and 71.5 (3.4) at T1, T2 and T3 respectively. Statistically there is a significant difference between group VCV and PCV at T1 (p=0.013). There is no significant statistical difference between VCV and PCV groups at T2 (p=0.674) and T3 (p=0.053).

Keywords: PCV, VCV, hemodynamic changes

Introduction

Laparoscopic cholecystectomy has replaced classical open cholecystectomy in the evolving surgical field. The increase in intra-abdominal pressure during pneumoperitoneum has some consequences. The cardio-pulmonary and metabolic changes during pneumoperitoneum are complex and associated with the level of intra-abdominal pressure (which gives rise to increase in airway pressures), duration of pneumoperitoneum, patient position and the ventilation mode [1].

Volume controlled ventilation (VCV) with constant flow is the traditional mode of ventilation during laparoscopic surgery. Although the use of VCV in anaesthesia can guarantee the target minute ventilation; a constant flow may lead to higher peak inspiratory pressures (PIP), that can lead to shear stress injury, barotrauma and volutrauma to the alveoli leading to micro-atelectasis and inflammatory mediator

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release characteristic of ventilator-associated lung injury [2].

Pressure controlled ventilation (PCV) is an alternate mode of ventilation which utilizes a decelerating flow and constant pressure. Ventilator parameters are automatically changed with each patient breath, to offer the target tidal volume without increasing airway pressures. This flow pattern has a high initial rise followed by a decrease and helps to achieve the required tidal volume at lower peak inspiratory pressures, and oxygenation is also better due to the initial high flow rates [3]. The resulting tidal volume depends on the pressure limit and the respiratory system compliance and resistance. Furthermore, the limitation of pressure levels has a positive effect on the patient's haemodynamics and might even reduce the risk of barotrauma. Recently, few studies comparing the efficacy of PCV over other modes on selected surgical procedures have been studied and has shown variable results [4].

Methodology

Source of data

Data will be collected from all the consenting patients who will be scheduled for elective laparoscopic cholecystectomy surgery under general anaesthesia with endotracheal intubation in Department of Anaesthesiology.

Sample size

Based on the study conducted by Assad MO *et al*. in 2016, the outcome variable peak inspiratory pressure is considered for sample calculation. We hypothesised the minimum difference of 2.5 cmH_20 and standard deviation of 3.56 for volume-controlled ventilation (VCV) and 3.9 for PCV. The sample size was calculated with a statistical power of 80% and 95% confidence interval. The estimated sample size was 36 for each group. Thus, the total sample size for this study is 72.

Study design

Prospective randomised clinical study.

Inclusion criteria

1. Patients of either gender.
2. Belonging to American society of Anaesthesiologists (ASA) physical status 1-2.
3. Aged between 18-60 yrs.
4. Undergoing elective laparoscopic cholecystectomy surgery under general anaesthesia.

Exclusion criteria

1. Patients unwilling to give consent.
2. Respiratory infections in the past 3 weeks.
3. Known hypersensitivity to any drugs used in this study.
4. Patients in whom surgery was converted to open procedure.
5. Patients with cardiac, renal or hepatic insufficiency.
6. Patients with cerebrovascular or neuromuscular diseases.
7. Pregnant women.
8. Severe obstructive or restrictive pulmonary disease (defined as less than 50% of

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predicted values of forced vital capacity and forced expiratory volume in 1 second), previous lung surgery or home oxygen therapy.
9. Hemodynamic instability.
10. BMI exceeding >30 kg/m^2.

Institutional ethical committee approval was obtained before commencement of the study. Informed written consent was obtained from all patients.

All the patients were examined during the pre-operative visit, a day before surgery. Routine blood investigations including complete haemogram, renal function test, blood sugar, chest X-ray and electrocardiogram (ECG) was carried out and recorded. They were kept nil orally 8 hours before surgery and were pre-medicated with alprazolam 0.5 mg per oral (PO), the night before surgery and ranitidine 150 mg and ondansetron 2 mg PO on the morning of surgery.

In the operating room, ECG, non-invasive blood pressure (NIBP) and pulse oximeter for peripheral oxygen saturation (SpO_2) are attached. An intravenous (IV) line and an intra-arterial line was secured.

A baseline arterial blood gas (ABG) analysis was done.

All the patients were randomised into two groups (group P and group V) by using computer generated random number table.

Group P: Received pressure-controlled ventilation (PCV) during general anaesthesia.

Group V: Received volume-controlled ventilation (VCV) during general anaesthesia.

The patients were pre-medicated with IV midazolam 0.03 mg/kg.

Anaesthesia was induced with propofol 2-3 mg/kg, fentanyl 1-2 mcg/kg, vecuronium 0.1-0.2 mg/kg. Patients were manually ventilated with 100% oxygen, intubation will be performed after 3 minutes and mechanical ventilation was initiated.

After trocars placement, patients were placed in a modified reverse Trendelenburg position (30 degrees head up and 30 degrees tilt left). Following positioning, patients were randomly assigned to one of the two modes of mechanical ventilation.

Patients were ventilated by Space Labs-Blease Sirius Anaesthesia Machine (OSI Systems, Inc. Hawthorne, California).

In the PCV group (group A), inspiratory pressure was not exceeded 30 cmH_2O, the following parameters were adjusted as follows: frequency 12-18/min, I:E ratio 1:2, PEEP 5cm H_2O and $ETCO_2$ 30-35 mmHg.

In the VCV group (group B), adjustments were done as, tidal volume 8-10 ml/kg, frequency 12-14/min, I:E ratio 1:2, PEEP 5 cmH_2O and $ETCO_2$ 30-35 mmHg.

Anaesthesia was maintained with sevoflurane 1-2%, 60% N_2O and 40% O_2; analgesia was maintained with fentanyl 2-3 mcg/kg and muscle relaxation with vecuronium.

The intraperitoneal pressure was adjusted to 12 ± 2 mmHg. Immediately after the surgical specimen removal and achieving of hemostasis, the CO_2 was removed and the patients were returned to the supine position.

At the end of the procedure, neuromuscular blockade was antagonised with 0.04 mg/kg neostigmine and glycopyrrolate 0.01 mg/kg intravenous. The trachea was extubated when patient is fully awake with no residual neuromuscular paralysis.

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Results

Table 1: Comparison of heart rate between study groups

Heart Rate	Group V VCV Group		Group P PCV Group		p value
	Mean	SD	Mean	SD	
T1 (5 mins after induction of anaesthesia in supine position and before initiation of the pneumoperitoneum)	71.3	5.1	68.8	3.0	0.013*
T2 (Post pneumoperitoneum and Trendelenburg position at 15 mins)	72.1	4.6	71.7	3.1	0.674
T3 (Post pneumoperitoneum and Trendelenburg position at 60 mins)	73.4	4.5	71.5	3.4	0.053

Note: p value* significant at 5% level of significance ($p<0.05$).

The mean (SD) of heart rate in the VCV group are 71.3 (5.1), 72.1 (4.6) and 73.4 (4.5) at T1, T2 and T3 respectively. In the PCV group are 68.8 (3.0), 71.7 (3.1) and 71.5 (3.4) at T1, T2 and T3 respectively. Statistically there is a significant difference between group VCV and PCV at T1 (p=0.013). There is no significant statistical difference between VCV and PCV groups at T2 (p=0.674) and T3 (p=0.053).

Table 2: Comparison of systolic BP between study groups

Systolic BP	Group V VCV Group		Group P PCV Group		p value
	Mean	SD	Mean	SD	
T1 (5 mins after induction of anaesthesia in supine position and before initiation of the pneumoperitoneum)	108.5	7.2	106.2	3.5	0.083
T2 (Post pneumoperitoneum and Trendelenburg position at 15 mins)	110.5	7.0	111.4	2.7	0.479
T3 (Post pneumoperitoneum and Trendelenburg position at 60 mins)	109.9	6.4	115.6	2.7	<0.001*

Note: p value* significant at 5% level of significance ($p<0.05$).

The mean (SD) of systolic BP in the VCV group are 108.5 (7.2), 110.5 (7.0) and 109.9 (6.4) at T1, T2 and T3 respectively. In the PCV group are 106.2 (3.5), 111.4 (2.7) and

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115.6 (2.7) at T1, T2 and T3 respectively. Statistically there is no significant difference between group VCV and PCV at T1 (p=0.083), T2 (p=0.479). But there is statistically significant difference between VCV and PCV groups at T3 (p=0.001).

Table 3: Comparison of diastolic BP between study groups

Diastolic BP	Group V VCV Group		Group P PCV Group		p value
	Mean	SD	Mean	SD	
T1 (5 mins after induction of anaesthesia in supine position and before initiation of the pneumoperitoneum)	67.4	2.2	65.0	3.1	<0.001 *
T2 (Post pneumoperitoneum and Trendelenburg position at 15 mins)	67.8	2.3	71.0	2.5	<0.001 *
T3 (Post pneumoperitoneum and Trendelenburg position at 60 mins)	68.2	2.6	74.1	2.4	<0.001 *

Note: p value* significant at 5% level of significance (*p*<0.05).

The mean (SD) of diastolic BP in the VCV group are 67.4 (2.2), 67.8 (2.3) and 68.2 (2.6) at T1, T2 and T3 respectively. In the PCV group are 65.0 (3.1), 71.0 (2.5) and 74.1 (2.4) at T1, T2 and T3 respectively. Statistically there is a significant difference between group VCV and PCV at T1 (p=0.001), T2 (p=0.001) and T3 (p=0.001).

Table 4: Comparison of mean BP between study groups

Mean BP	Group V VCV Group		Group P PCV Group		p value
	Mean	SD	Mean	SD	
T1 (5 mins after induction of anaesthesia in supine position and before initiation of the pneumoperitoneum)	81.1	3.4	78.6	2.5	0.001 *
T2 (Post pneumoperitoneum and Trendelenburg position at 15 mins)	82.0	3.3	84.4	2.0	<0.001*
T3 (Post pneumoperitoneum and Trendelenburg position at 60 mins)	82.1	3.2	88.0	1.7	<0.001*

Note: p value* significant at 5% level of significance (*p*<0.05).

The mean (SD) of mean BP in the VCV group are 81.1 (3.4), 82.0 (3.3) and 82.1 (3.2)

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at T1, T2 and T3 respectively. In the PCV group are 78.6 (2.5), 84.4 (2.0) and 88.0 (1.7) at T1, T2 and T3 respectively. Statistically there is a significant difference between group VCV and PCV at T1 (p=0.001), T2 (p=0.001) and T3 (p=0.001).

Discussion

Our study was conducted on patients with no underlying lung pathology. We postulated that the effects of the different modes on the laparoscopic physiology are better appreciated in healthy patients. The alveolar pathology in restrictive and obstructive lung diseases and its interaction with the laparoscopy-induced changes are absent in our patients, and hence, the direct effects of the modes are better appreciated.

Similar studies comparing the two modes of ventilation among different surgical cohorts showed different varying results. Tyagi *et al.* [5] have observed lower P-peak values and higher compliance without any changes in PaO_2 values in PCV mode. Gupta *et al.* [6] also reported lower P-peak levels and dead space with higher PaO_2 in the PCV mode. In the Balick-Weber study [7], passage from the VCV to the PCV mode resulted in a fall in the P-peak values and an increase in the compliance without any significant differences in oxygenation, systolic and diastolic heart functions. Ogurlu *et al.* [8] have reported similar findings during laparoscopic gynecological operations.

Cadi *et al.* [9] randomly allocated 36 patients to receive PCV or VCV modes of ventilation in patients undergoing bariatric surgery and found that the peak pressures were lower in PCV group. No significant change in mean pressures was noted.

However, in a study by Dion *et al.* [10] 20 obese patients undergoing laparoscopic sleeve gastrectomy received VCV, PCV modes in a random sequence and the authors found the peak pressures were significantly lower in the PCV mode compared to the volume-controlled mode similar to our observations.

A review by Aldenkortt *et al.* [11], assessed 13 studies comparing PCV and VCV modes that included 500 obese patients. They concluded that there was no significant difference in airway pressures between the two groups.

Boules and Ghobrial [12] and Song *et al.* [13] studied the effects of PCV and VCV on various parameters, including respiratory mechanics and haemodynamics during one-lung ventilation (OLV). Results were similar to our study showing that peak airway pressure was significantly lower in PCV compared to VCV in all stages of the study ($p<0.050$). In addition, the P_{mean} (mean airway pressure) showed lower values in the PCV group. They indicated that PCV group provided lower airway pressures compared to VCV.

Oxygenation was well maintained in both the group of patients throughout the surgery. Oxygenation depends on the FiO_2, alveolar ventilation and intrapulmonary shunts. The inspired oxygen concentration in our study was constant, and alveolar ventilation was uncompromised (mean pressures were normal). We inferred that the ventilation-perfusion mismatch which is expected to be higher with anaesthesia, and pneumoperitoneum has not been significant in our patients to impair oxygenation. Our finding has been consistent with many studies conducted on ventilation-perfusion changes during laparoscopy.

Anderson *et al.* [14] conducted a similar study on V/Q distribution using MIGET scan in humans and showed similar finding explaining why oxygenation is by and large well preserved in healthy adults. However, Cadi *et al.* [9] and Gupta *et al.* [6] found out that oxygenation was better maintained in PCV than VCV in obese patient undergoing bariatric surgeries. The difference in their results and our results could be attributed to the difference in the patient profiles in both the studies.

The major limitation of our study is, it included healthy subjects, it is a single-hospital study and is done on patients subjected to one particular type of surgery. Surgical manipulations as in robotic surgeries may alter the results of the study. In addition, our study being conducted in patients with normal lungs and studies on patients with underlying lung diseases subjected to such surgeries may also differ from results of our study.

No other differences were noted between the two modes of ventilation when considering hemodynamic variables.

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