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Original Research Article

PROSPECTIVE RANDOMIZED DOUBLE-BLIND STUDY TO COMPARE HEMODYNAMIC AND RESPIRATORY PARAMETERS AMONG PRESSURE CONTROLLED VENTILATION AND VOLUME CONTROLLED VENTILATION IN LAPAROSCOPIC CHOLECYSTECTOMY CASES

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ABSTRACT

Background: Laparoscopic cholecystectomy offers many advantages including reduced pain, fast recovery and reduced hospital stay. However, pneumoperitoneum used during surgery, positioning and raised intrabdominal pressure may have adverse effects on respiratory and hemodynamic parameters. We compared two modes of ventilation ie pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV) during laparoscopy to observe its effects on respiratory, haemodynamic and blood gas parameters.
Materials and Methods: Patients were divided into two groups of 26 each to receive either PCV mode of ventilation or VCV. Standard monitoring including ECG, IBP, EtCO2, and SpO2 was used. Anaesthesia was given using propofol, vecuronium and fentanyl and was maintained with oxygen, nitrous and sevoflurane. Respiratory, hemodynamic and blood gas parameters were recorded throughout procedure.
Results: Demographic data as well as hemodynamic parameters and blood gas parameters were comparable in two groups ($P > 0.05$). Peak airway pressure and plateau pressure were significantly lower in PCV group ($P < 0.05$). Mean airway pressure was higher in PCV group although for limited time.
Conclusion: PCV is better mode of ventilation as it reduces peak and plateau airway pressure without compromising hemodynamic parameters.
Key words: Pressure-control ventilation, volume-control ventilation, peak-airway pressure, mean airway pressure.

INTRODUCTION

Laparoscopic cholecystectomy has emerged as gold standard for management of disorders of gall bladder due to minimal pain, earlier recovery and shorter hospital stay.[1,2] General anaesthesia used during surgery alters various respiratory parameters including decrease in total lung capacity, functional residual capacity and lung compliance. Creation of Pneumoperitoneum with Trendelenburg position may cause exacerbation of this. Further, pneumoperitoneum used during laparoscopy not only causes rise in intra-abdominal pressure and intra-thoracic pressure but also alters various physiological parameters of the body including increased airway resistance, increased peak airway pressures and partial pressure of CO2 in arteries. This can lead to atelectasis of bases of lung due to repeated closure of smaller airways. Apart from this, CO2 pneumoperitoneum can cause rise in systemic vascular resistance, increase in mean arterial pressure, decreased venous return and reduced cardiac output.[3,4,5]

Variety of ventilation strategies have been employed to prevent respiratory complications including atelectasis and desaturation during laparoscopy. Amongst this pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV) are more often considered. PCV limits inspiratory pressure thereby reducing barotrauma and volutrauma during laparoscopy. Further, inspiratory time can be extended and adequate level of positive end-expiratory pressure (PEEP) can be added to ensure opening of collapsed alveoli.[6,7]

However, VCV remains more popular mode of ventilation for intraoperative use. It has preset parameters including tidal volume and respiratory frequency while inspiratory pressure is variable. But, high peak pressure occurring intraoperatively, particularly during laparoscopic surgery, may necessitate change in frequency and tidal volume.

Although these two modes are recommended alternative to each other to be used intraoperatively, effect of each mode along with CO_2 pneumoperitoneum needs to be considered during selection of mode of ventilation.[8,9] Hence we aimed to study effects of effects of these two modes of ventilation during laparoscopic cholecystectomy on hemodynamic, respiratory and blood gas parameters.

MATERIALS AND METHODS

This was prospective randomized double-blind study conducted in tertiary care institute after obtaining institutional ethics committee approval. Study was conducted during period of June 2017 to December 2019. This study was conducted in accordance with Good Clinical Practice and in a manner to conform to the Helsinki Declaration of 1975, as revised in 2013 concerning human rights. Well-being and safety of patients were maintained during study. Fifty-two patients of either gender of age group 18-60 years of ASA I and II grades receiving general anaesthesia for laparoscopic cholecystectomy were randomly allocated in two groups of 26 each using block randomisation and computer generated sequence.

Patients refusing to give consent, ASA grade III/IV, patients with morbid obesity (BMI exceeding 35 kg/ m^2), patients with history of cardiac, pulmonary, hepato-renal, endocrine, cerebrovascular and neuromuscular disease or thoracic surgery, person with dementia or other mental or psychiatric symptoms, intra-operative usage of an airway device other than a tracheal tube and requirement for mechanical ventilation in the postoperative period were excluded.

Patient were evaluated preoperatively including detailed airway examination and investigated according to institutional protocol. Study protocol was explained to patient and written informed consent was obtained. Arterial Blood Gas (ABG) Analysis was also explained.

A night prior to surgery, patient was given tab alprazolam 0.25 mg and tab pantoprazole 40 mg. On day of surgery, NPO status and consent was checked. An iv line was secured and RL was started. Patients were attached with standard monitors including ECG, SPO_2, NIBP, $ETCO_2$, temperature probe and baseline parameters were recorded. Patients were premedicated with midazolam 0.02mg/kg, Inj Fentanyl 2 μg /kg, pantoprazole 40mg and Inj glycopyrrolate 4mcg/kg IV. After Allen test and local anesthetic infiltration, a cannula was placed to the radial artery to monitor arterial pressures. Blood sampling was made for baseline arterial blood gases (ABG) analysis. Anesthesia was induced with propofol 2 mg/kg. and vecuronium 0.12 mg/kg was given to facilitate tracheal intubation. Anesthesia was maintained with 1 MAC of sevoflurane in a mixture of oxygen and nitrous oxide (FiO_2: 50 %). Fentanyl 0.5–1 μg/kg was added to maintain systolic arterial pressure within ±20 % of the baseline value. The ventilator parameters were set as respiratory rate: 12 breaths/min (constant during anesthesia); inspiration time/expiration time: 1/2 and fresh gas flow 1.5-2 L/min.

Patients in Group PC were given pressure support to form 8 ml/kg tidal volume (pressure support level was adjusted to maintain the same tidal volume during pneumoperitoneum); while Group VC was maintained at 8 ml/kg tidal volume, both were calculated using predicted body weight. All patients were maintained with 5 cmH_2O positive-end expiratory pressure (PEEP). After intubation, before pneumoperitoneum, heart rate, arterial pressures, $EtCO_2$, peak, plateau and mean airway pressures (P-peak, P-plateau, and P-mean respectively) were recorded on monitor and dynamic compliance (C-dyn) levels was calculated and measured. Parameters were recorded every 15 minutes till completion of surgery.

Pneumoperitoneum was created by CO_2 insufflation and intra-abdominal pressure was maintained at 12 mmHg by means of an automatic insufflator. Thirty minutes after the pneumoperitoneum, the respiratory and hemodynamic parameters were recorded again, and sampling for ABG repeated. All patients received paracetamol 1 g IV after gallbladder extraction; and ondansetron 4 mg before extubation. Skin incisions were infiltrated with 15–20 ml of bupivacaine 0.5 % before closure. Neuromuscular blockade was antagonized with neostigmine 0.05mg/kg and glycopyrrolate 80 mcg/kg and trachea was extubated. Hemodynamic parameters were recorded and blood sampling for ABG repeated for the last time 60 min after extubation (without supplemental oxygen).

The quantitative data was represented as their mean ± SD. Categorical and nominal data was expressed in percentage. The t-test was used for analyzing quantitative data, or else non-parametric data was analyzed by Mann Whitney test and categorical data was analyzed by using chi-square test. The significance threshold of p-value was set at <0.05. All analysis was carried out by using SPSS software version 21.

RESULTS

Present study was conducted on 52 patients undergoing laparoscopic cholecystectomy which were divided into two groups of 26 each receiving either PCV or VCV.

The two groups were comparable with respect to demographic and baseline parameters including hemodynamics. We asked surgeons to keep intraabdominal pressure between 12-14 mmHg in both groups. (Table 1)

Table 1: Comparison of Demographic parameters in Two Groups

Parameter	Group VCV (Mean±SD)	Group PCV (Mean±SD)	P value
Age (years)	36.41 ±10.10	37.67 ±10.85	0.81
BMI (Kg/m2)	22.34±3.21	23.17±2.97	0.37
Male: Female (%)	5(19.2%):21(80.8%)	6(23.1%) ±20(76.9%)	1.00
ASA 1: 2(%)	23(88.5%):3(11.5%)	21(80.8%):5(19.2%)	0.7
Duration of surgery(minutes)	64.32±19.87	61.45±23.18	0.23
Total volume of CO_2 insufflated	75±35)	68±28	

BMI: body mass index, PCV: pressure control ventilation, VCV: volume control ventilation ASA: American society of anesthesiologists. P value<0.05 is considered as significant.

There was no difference in two groups when hemodynamic variables were compared at different time interval intraoperatively (Table 2). No difference was observed in mean respiratory rate, EtCO2 and SpO2 values in two groups (Table 2)

Table 2: Hemodynamic and respiratory data recorded at different time interval

Parameters	15 minutes (Mean±SD)		30 minutes (Mean±SD)		45 minutes (Mean±SD)		60 minutes (Mean±SD)		75 minutes (Mean±SD)	
	VCV	PCV	VCV	PCV	VCV	PCV	VCV	PCV	VCV	PCV
HR/min	69.53± 10.64	69.25± 9.09	68.88± 9.83	66.42± 8.94	65.33± 8.70	64.75± 8.44	65.15± 8.60	64.58±8.24	65.42±8.60	64.40±8.14
MAP (mmHg)	100.02 ±6.35	99.93± 6.37	99.07± 5.97	98.92 ±5.81	98.98 ±5.89	98.37±5.67	98.4 ±5.68	98.12 ±5.50	98.25 ±5.21	98.15 ±5.29
Mean RR	13.91 ±2.13	13.85 ±1.82	13.76 ±1.97	13.97 ±1.79	13.61 ±1.74	13.78 ±1.69	13.57 ±1.72	13.74 ±1.65	13.63 ±1.72	13.70 ±1.63
$EtCO_2$ mmHg	36.89 ±1.51	36.77 ±1.49	37.14 ±1.51	37.22 ±1.58	37.19 ±1.53	37.14 ±1.44	37.22 ±1.48	37.19± 1.47	37.40 ±1.98	37.11±1.49
SpO_2%	99.21 0.55	99.05 0.30	99.25 0.56	99.10 0.30	99.14 0.47	99.06 0.34	99.14 0.52	99.06 0.36	99.08 0.47	99.000.28

PCV: pressure control ventilation, VCV: volume control ventilation, MAP: mean arterial pressure, RR: respiratory rate. P value<0.05 is considered as significant.

Peak airway pressures and Pplateau in the VCV and PCV groups were similar at baseline. However, at 15 min after the start of surgery, the peak airway pressure and Pplateau started significantly decreasing in the PC group as compared with the VC group (p<0.05). The difference was observed till 60th minute (Table 3). Mean airway pressures in the VC and PC groups were similar at baseline. However, at 30 min after the start of surgery, the mean airway pressure was significantly more in the PC group and difference was observed till 45th minute, after which the groups were comparable. Dynamic compliance in the VC and PC groups were similar at baseline. However, at 15 min after the start of surgery, the compliance was significantly more in the PC group as compared with the VC group at 15 and 30th minute (p<0.05).

Table 3: Respiratory data (airway pressures) recorded at different time interval

Parameters	15 minutes (Mean±SD)		30 minutes (Mean±SD)		45 minutes (Mean±SD)		60 minutes (Mean±SD)		75 minutes (Mean±SD)	
	VCV	PCV	VCV	PCV	VCV	PCV	VCV	PCV	VCV	PCV
P_{peak}	24.10 ±4.80	20.45* ±2.99	23.90 ±4.90	20.38* ±2.91	23.78± 3.81	20.70* ±2.78	23.44±3.97	20.35* ±2.89	22.56 ±4.18	20.77±3.25
$P_{plateau}$	22.70 ±4.40	19.13* ±2.67	22.50 ±4.50	19.06* ±2.59	22.38 ±3.41	19.38* ±2.46	22.04 ±3.57	19.03* ±2.57	21.41 ±3.78	19.98 ±2.93
P_{mean}	9.91 ±0.60	9.00 ±1.09	9.68 ±1.10	10.55* ±0.17	9.53 ±0.99	10.76* ±0.69	9.19 ±0.91	9.97 ±0.77	9.43 ±1.07	9.91 ±0.81
Dynamic compliance	35.67 ±7.86	41.59* ±7.91	23.88 ±7.77	29.87* ±6.54	25.69 ±7.69	27.81 ±7.61	30.22 ±8.80	31.76 ±7.91	33.45 ±11.30	36.19 ±8.90

Ppeak: peak airway pressures and Pplateau: plateau airway pressure, Pmean: mean airway pressure

PCV: pressure control ventilation, VCV: volume control ventilation. P value<0.05 is considered as significant

There was no difference between the two groups in mean pH and blood gases in two groups perioperatively. (Table 4)

Table 4: Comparison of data on blood gas analysis

Parameters	Preoperative (Mean±SD)		Intraoperative (Mean±SD)		Postoperative (Mean±SD)	
	VCV	PCV	VCV	PCV	VCV	PCV
Mean pH	7.40±0.02	7.40±0.03	7.33±0.02	7.39±0.01	7.42±0.02	7.41±0.01
Mean $PaCO_2$ (mm Hg)	41.11±1.81	41.18±1.87	42.69±1.90	42.38±1.85	44.54 ±1.84	44.31± 1.82
Mean PaO_2 (mm Hg)	84.40±8.50	83.40±10.4	194.50±17.6	200.30±19.8	95.01±8.45	94.90±7.63

P value<0.05 is considered as significant.

DISCUSSION

Laparoscopic cholecystectomy is commonly performed procedure due to many advantages including smaller incision, reduces pain and need for analgesia, shorter hospital stays and earlier mobilization compared to open procedure.[10]

However, creation of pneumoperitoneum and positioning of patient may have adverse effects on hemodynamic parameters as well as respiratory mechanics. Hence, it is mandatory to choose appropriate mode of ventilation to reduce adverse effects while performing such procedures. Further, it is also essential to keep intrabdominal procedures near physiological range (≤14 mmHg) so as to reduce its adverse effects on hemodynamics and respiratory parameters. When intraabdominal pressure is maintained at 14 mm Hg, hemodynamic and respiratory changes that may occur is related to anesthetic technique and agent used, ventilation strategy used, amount of CO2 insufflated and surgical duration.[11,12,13,14]

In our study, we could demonstrate efficacy of PCV compared to VCV. We found that PCV had better respiratory dynamics and compliance compared to VCV, though, gaseous exchange did not improve with it. These finding were similar to those of previous studies.[15]

Reduction in peak airway pressure occurs in variety of lung conditions when PCV is used including acute lung injury, ARDS, one lung ventilation and obesity and is well documented previously16, 17, 18. Decreased peak airway pressure during PCV is due to decelerating inspiratory flow pattern, in which maximum value is reached early in inspiration which is followed by a deceleration of the flow rate.[19] This pattern of flow during initial part results in early alveolar inflation causing rise in mean airway pressure. This rise in mean airway pressure correlates with alveolar pressure which may enhance oxygenation.[20] However, in contrast to previous studies, our study could not demonstrate any improvement in gaseous exchange. This could be due to our focus which was peak and mean airway pressures rather gaseous exchange and the study was not powered to detect changes in oxygenation.

When we compare other respiratory parameters, Ppeak was significantly lower in PCV compared to VCV at all times and this is important finding. This reduces hemodynamic compromise as well as barotrauma. It was also observed that Pplateau was on lower side in PCV, although was not consistent throughout study. This may be considered as pure coincidence. EtCO2 values in both groups were comparable at all times and so also SpO2 in both groups. Although few previous studies demonstrated better EtCO2 values in PCV group,[21] others could not find any difference.[22,23]

Mihalj et al,[24] found PCV and VCV to be equally effective in terms of ventilation, oxygenation and hemodynamic stability. However, they found PCV to be more effective in obese patients (BMI >25) in terms of lower airway pressures and EtCO2.

Tyagi et al,[15] studied effect of both mode of ventilation in laparoscopic cholecystectomy patients and found PCV to be better than VCV in terms of peak airway pressure, Pplateau airway pressure and mean airway pressure. They found both group of patients to be hemodynamically stable and could not demonstrate any difference in oxygenation and EtCO2 values. Our findings were consistent with this study.

Hemodynamic may be adversely affected in pressure-controlled ventilation owing to increase in mean airway pressure which affects pleural pressure. However, despite these facts, we did not find any alteration in hemodynamics and this is attributable to small change in mean airway pressure.

Given these findings, PCV can be considered as preferred mode of ventilation as it maintains lower peak airway pressure reducing risk of volutrauma and barotrauma as well as minimal effects on hemodynamic variables. However, VCV ensures constant tidal volume with every breath maintaining precise ventilation control which is essential in patients with varying lung compliance. This may occur at the cost of higher airway pressure which potentially can cause ventilator-induced lung damage. However, choice of ventilation needs to be individualized depending upon surgical factors and patient physiology.

Hence, based on our results it can be stated that both modes of ventilation are equally effective in terms of oxygenation, adequate ventilation and hemodynamic stability. However, PCV found to be more advantageous in laparoscopic cholecystectomy patients as it had specific advantages pertaining to peak airway pressures, Pplateau pressure and mean airway pressure which reduces incidence of barotrauma. However, large number of patients needs to be evaluated to validate study findings. Also, multi centric study will help to reduce the regional bias originates from a single center-based study.

CONCLUSION

PCV is better mode of ventilation as it reduces peak and plateau airway pressure without compromising hemodynamic parameters.

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