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A COMPARATIVE STUDY OF PRESSURE CONTROLLED VENTILATION AND VOLUME CONTROLLED VENTILATION WITH RESPECT TO HAEMODYNAMICS AND STRESS RESPONSE FOR PATIENTS UNDERGOING GENERAL ANAESTHESIA WITH ENDOTRACHEAL INTUBATION WITH CONTROLLED VENTILATION IN PRONE POSITION

Anaesthesiology

Joshi Aishwarya	Department of Anaesthesiology and Critical care, MVJ Medical College and Research Hospital, Bangalore, Karnataka, India -562114
Kulkarni Prasad	Department of Anaesthesiology and Critical care, MVJ Medical College and Research Hospital, Bangalore, Karnataka, India -562114
Kumar Shailesh	Department of Anaesthesiology and Critical care, MVJ Medical College and Research Hospital, Bangalore, Karnataka, India -562114
K S Shashanka	Department of Anaesthesiology and Critical care, MVJ Medical College and Research Hospital, Bangalore, Karnataka, India -562114

ABSTRACT

The most often used ventilation mode in general anesthesia is volume-controlled ventilation (VCV). PCV, which is usually available with modern anaesthesia ventilators, should be preferred over the conventional VCV mode in the various surgeries in prone position, as it offers lower airway pressures. Study was performed on 60 patients who were included in the study based on inclusion and exclusion criteria. Out of 60 patients 30 patients were assigned to PCV group and 30 patients were assigned to VCV group.We compared the perioperative hemodynamic values HR, SAP, MAP, and respiratory parameters during mechanical ventilation ETCO2, P peak ,P plateau, P mean and perioperative arterial blood gas PH, PaCO2, PaO2 and systemic stress response by cortisol , glucose, and lactate levels in PCV and VCV mode

KEYWORDS

Mechanical ventilation, volume-controlled ventilation (VCV), pressure controlled ventilation (PCV), Airway pressure, Systemic stress response, Cortisol, Lactate.

INTRODUCTION

The most often used ventilation mode in general anesthesia is volume-controlled ventilation (VCV). PCV, which is usually available with modern anaesthesia ventilators, should be preferred over the conventional VCV mode in the various surgeries in prone position, as it offers lower airway pressures. Prone position during general anesthesia for special surgical operations may be related with increased airway pressure, decreased pulmonary and thoracic compliance that may be explained by restriction of chest expansion and compression of abdomen during prone position. The optimum ventilation mode for anesthetized patients in prone position has not been described and studies comparing volume controlled ventilation (VCV) and pressure controlled ventilation (PCV) during prone position are limited.

Objectives of the study was to evaluate the relation between mechanical ventilation mode, stress response and associated haemodynamic changes in patients undergoing general anaesthesia with endotracheal intubation with controlled ventilation in prone position. To compare the perioperative hemodynamic values HR, SAP, MAP, and respiratory parameters during mechanical ventilation ETCO2, P peak ,P plateau, P mean and perioperative arterial blood gas PH, PaCO2, PaO2 and systemic stress response by cortisol ,glucose, and lactate in pressure controlled ventilation and volume controlled ventilation.

Volume-Controlled Ventilation

Volume-controlled ventilation allows the clinician to set the volume to delivered with each breath with fixed volume delivery and variable pressure depending upon the patient's pulmonary compliance and airway resistance, Volume will remain constant in spite of changes in the patient's condition. The advantage of volume control is the ability to regulate both tidal volume and minute ventilation (a product of tidal volume and frequency).

Pressure-Controlled Ventilation

The pressure-controlled mode allows the clinician to set a peak inspiratory pressure for each mechanical breath. Since pressure remains constant, volume and minute ventilation will vary with changes in the patient's pulmonary compliance or airway resistance. Should the patient's compliance worsen or airway resistance increase, the peak inspiratory pressure terminates soon and the tidal volume and minute ventilation decreases. The advantage of the pressure-controlled mode is that the lungs can be protected from excessive pressures, preventing ventilator-induced lung injury(VILI).

Volume-controlled ventilation (VCV) that utilizes a constant flow to deliver target tidal volume ensures minute ventilation, but reduced thoracic compliance of the patient may result in high airway pressures and increase the risk of ventilator-induced lung injury. Pressure-controlled ventilation (PCV), with its high and decelerating inspiratory flow pattern, has faster tidal volume delivery and diffused gas distribution. The same tidal volume setting, delivered by pressure controlled ventilation (PCV) versus volume controlled ventilation (VCV), may result in a lower peak airway pressure and reduced risk of barotrauma, but variable tidal volume may begenerated.

METHODS

Study was performed over the duration of 2 years from December 2020 – October 2022 in the department of Anesthesiology at MVJ Medical college and Research college and hospital. Study was performed on 60 patients who were selected according to the study's inclusion and exclusion criteria.

We include the patients belongs to 1. Age group- (30- 70) year old 2. ASA grading – (I – III) 3.All patients undergoing General Anaesthesia with endotreacheal intubation on controlled ventilation in prone position.4.Duration of surgery – 3 hours 5.Patients without any lung pathology.

We excluded the patients belongs to 1.Age - <30 year and >70 year.2.ASA IV and ASA V patients.3.Duration of surgery > 3 hours.4.COPD patients 5. Patients with difficult airway. 6. Patients on treatment with B-blockers7. Patients on antihypertensive therapy. 8.Patients with metabolic syndrome 9. Patient refusal.

Data collection was started after obtaining clearance from ethical committee. Informed consent was obtained from the patients.60 subjects were taken. Study was prospective clinical comparative study. Patients wererandomly allotted in 2 groups, PCV (n = 30) patients VCV (n = 30) patients.

We compared PCV and VCV modes in ventilator, in the patients who were undergoing the general anaesthesia with endotracheal intubation in prone position. Parameters were taken as tidal volume(8-10 ml/kg), Ppeak, PEEP. Haemodynamic parameters were heart rate (HR), mean arterial blood pressure(MAP), respiratory rate(RR), end tidal carbon dioxide levels(ETCO2) and perioperative arterial blood gas PH, PaCO2, PaO2 and systemic stress response by cortisol , glucose, and lactate.The following investigations were checked preoperatively 30 min before the surgery to evaluate the basic levels of the patient and to compare with intraoperative levels in two groups of ventilation modes of the study. Basic preoperative investigations were done for all patients to confirm fulfilling of both inclusion and exclusion criteria.

Blood sampling was made for baseline arterial blood gases (ABG) analysis and for cortisol, insulin and glucose levels to assess the systemic stress response.

ASA standard monitors were applied for the patients in the operating room and before starting anaesthesia consisting of non- invasive blood pressure (which was adjusted to measure systolic, diastoic and mean blood pressure every 5min), HR,ECG, pulse oximetry, ETCO2. Intravenous midazolam 0.03 mg/kg was administered. The monitor and anaesthetic machine which were used in the study were of same type in all patients.

General anaesthesia with endotracheal intubation was standardized for all the patients. Pre-oxygenation of the patient for 3 min with 100% O2 followed by induction of general anaesthesia for all the patients by IV injection of fentanyl 1mic/kg, Lidocaine (2%) 0.02mg/kg before Propofol injection, Propofol 2.5mg/kg and muscle relaxation with Vecuronium 0.12mg/kg. Maintenance of general anaesthesia by Isoflurane in a mixture of oxygen and N2Oand Vecuronium maintenance dose of 0.02 mg/kg was given every 20 min starting from the induction time.

The ventilatory parameters were set as respiratory rate: 12 breaths/min, inspiratory time /expiratory time: 1/2, positive end-expiratory pressure (PEEP): 5 cmH2O and FiO2: 50 %, which were constant during anesthesia in both groups. Patients in Group PCV were given pressure support to form 8 mL/kg tidal volume (pressure support level was adjusted to maintain the same tidal volume during anesthesia);while Group VCV was maintained at 8 mL/kg tidal volume. Tidal volume was calculated using predicted body weight in both groups. Heart rate, arterial pressures, end-tidal carbon dioxide pressure (EtCO2), peak, plateau and mean airway pressures (P-peak, P- plateau, P-mean respectively) were recorded after intubation during supine position.

All patients were transferred to classic prone position on a flat table. Head was in neutral position, the arms were raised beside the head, parallel chest rolls were placed from shoulder to hip on both sides, the legs were bent at the knees and all pressure points (forehead, elbow, knees, etc.) were padded and bolsters were placed at the xiphoid and symphysis pubis to keep the abdomen free for respiration.

After surgery was started and at the 30th minute of prone position, respiratory and hemodynamic parameters were recorded again and sampling for ABG, cortisol, insulin and glucose levels were repeated. For postoperative analgesia, paracetamol 1 g and tramadol 100 mg were administered and skin incisions were infiltrated with 10–15 ml of bupivacaine 0.5 % before closure. Anesthesia was maintained until the end of surgery. Neuromuscular blockade was antagonized with neostigmine 0.05 mg/kg and glycopyrolate 0.01 mg/kg and tracheal extubation was carried out when the patient was fully awake. Hemodynamic parameters were recorded and blood sampling for ABG, cortisol, insulin and glucose levels were repeated for the last time 60 min after extubation (without supplemental oxygen).

Statistical analysis:
A pilot study was conducted to determine the sample size. In the power analysis, according to the results of this pilot study, a sample size of 30 patients in each group was calculated to be sufficient to achieve 80% power and an α value of 0.05 by taking a delta value of 3.5 and a standard deviation of 4.8 into consideration. Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses. Descriptive statistics were given in terms of numbers and percentages for categorical variables, and in terms of the mean, standard deviation and the median for the numerical variables.

Inferential Statistics:
Shapiro Wilk test was used to observe for normality of data distribution and test results indicated that it followed normal distribution for all the study parameters except for age & weight. Accordingly, the inferential tests were performed using relevant parametric & non-parametric tests. Comparison of two independent groups of variables was carried out using the Student T test when meeting the normal distribution criteria, or by the Mann–Whitney U test when these criteria were not met. Mann Whitney test was used to compare the mean age and weight between 2 groups. Chi Square Test was used to compare the gender distribution and ASA grade distribution between 2 groups. Relationship between numerical variables was assessed by means of the Spearman Correlation Analysis. The differences between categorical variables were evaluated by the Chi square analysis. Statistical α (alpha) significance level was accepted with the 'p' value below0.05.

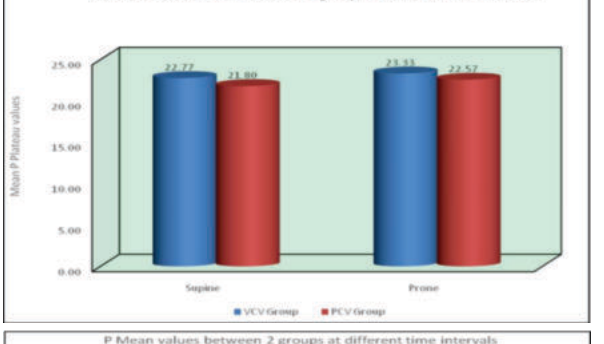
OBSERVATIONS AND RESULTS

There was no significant differences noted between 2 groups in terms of Mean age, gender, ASA grading, Heart Rate, Systolic Arterial Pressure, PaO2, PaCO2, pH , ETCO2, at different time intervals.

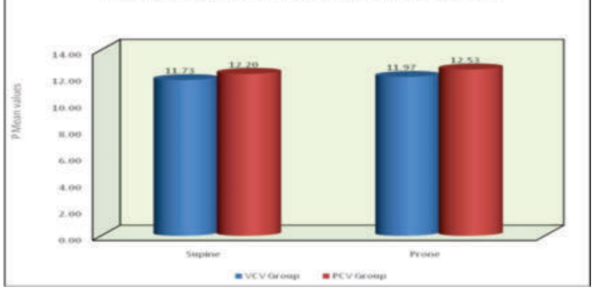
	VCV(n=30)		PCV(n=30)	
	Supine	Prone	Supine	Prone
Mean ETCO2(mmhg) SD	34.00	35.00	34.27	34.73
	1.37	2.21	1.89	1.80
Mean P Peak(mmhg) SD	27.57	26.83	23.87	25.80
	3.89	1.49	1.33	1.52
Mean P Plateau(mmhg) SD	22.77	23.33	21.80	22.57
	1.25	1.32	0.89	0.86
Mean P mean(mmhg) SD	11.73	11.97	12.20	12.53
	0.64	0.72	0.71	0.68

	VCV(n=30)			PCV(n=30)		
	Pre Operative	Prone	Post Operative	Pre Operative	Prone	Post Operative
Mean Heart rate (bpm) SD	80.07	87.00	88.97	79.63	84.73	88.93
	6.18	5.93	4.86	7.31	7.08	5.62
Mean SBP(mmhg) SD	123.13	117.60	132.73	124.53	120.20	131.67
	10.10	7.27	6.51	8.09	6.57	4.99
Mean Arterial Pressure(mmhg) SD	88.33	91.27	86.73	89.53	92.07	87.40
	3.60	4.59	3.81	3.95	4.73	4.44
Mean PaO2 (mmhg) SD	90.40	167.03	91.73	90.57	166.57	91.53
	3.62	18.70	2.73	3.07	16.71	2.39
Mean PaCO2(mmhg) SD	40.23	37.47	42.43	40.47	38.10	43.07
	3.13	4.63	3.67	1.94	3.89	2.99
Mean pH SD	7.370	7.398	7.395	7.379	7.387	7.392
	0.026	0.039	0.034	0.030	0.046	0.038
Mean Cortisol (mcg/dl) SD	12.08	24.90	27.52	12.05	23.74	25.62
	1.06	2.16	2.11	1.03	2.41	3.34
Mean Glucose(mg/dl) SD	91.70	115.30	128.43	92.70	110.30	124.37
	5.90	7.83	5.99	5.91	7.80	7.12
Mean lactate(mmol/l) SD	2.58	2.97	3.03	2.58	2.77	2.84
	0.38	0.37	0.37	0.40	0.31	0.35

Mean P Plateau values between 2 groups at different time intervals



P Mean values between 2 groups at different time intervals



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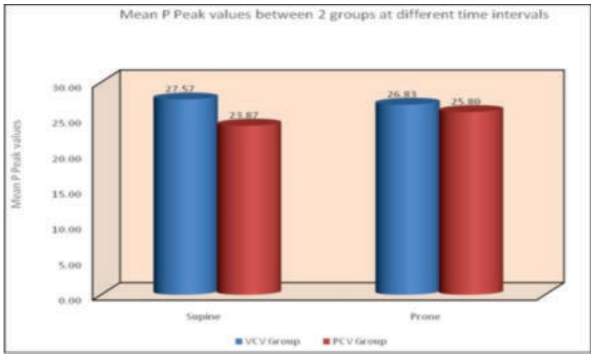

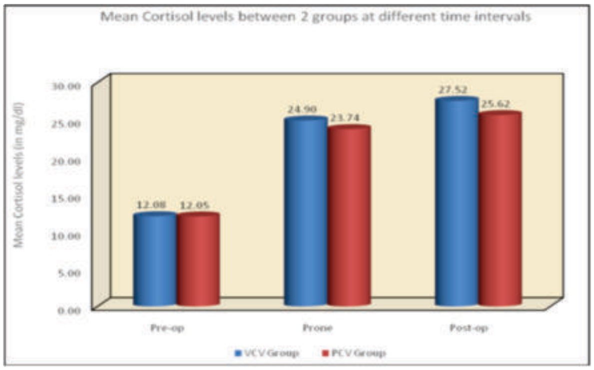

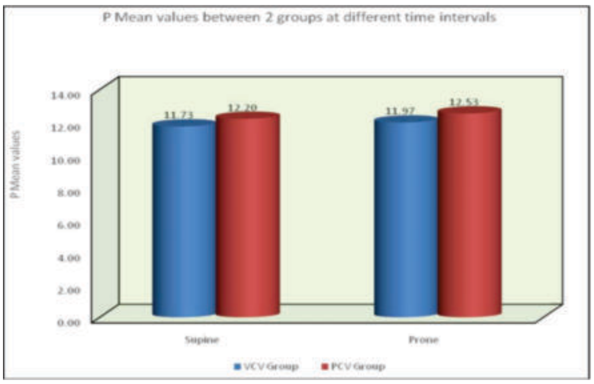

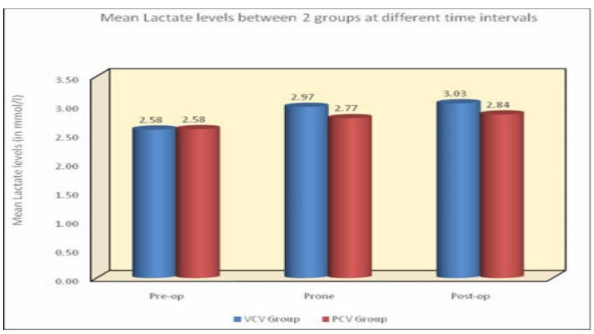

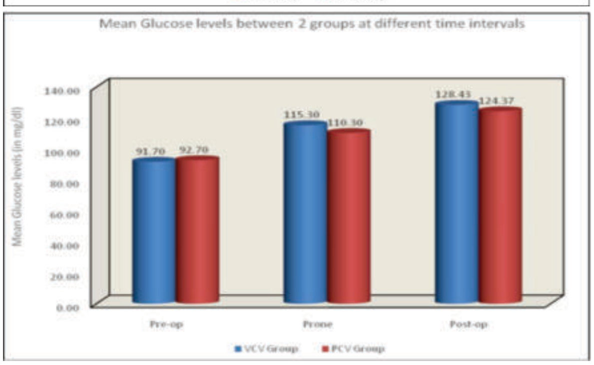

DISCUSSION

The mean P Peak values of PCV Group at Supine & Prone period was significantly lesser [23.87 ± 1.33 & 25.80 ± 1.52] as compared to VCV Group at Supine & Prone Period [27.57 ± 3.89 & 26.83 ± 1.49] and these differences in the P Peak values between 2 groups at Supine & Prone period was statistically significant at $p<0.001$ & $p=0.01$ respectively.

The mean P Plateau values of PCV Group at Supine & Prone period was significantly lesser [21.80±0.89&22.57±0.86] as compared to VCV Group at Supine & Prone Period [22.77±1.25&23.33±1.32] and these differences in the P Plateau values between 2 groups at Supine & Prone period was statistically significant at $p<0.001$ & $p=0.01$ respectively.

The mean P mean values of VCV Group at Supine & Prone period was significantly lesser [11.73 ±0.64&11.97 ±0.72] as compared to PCV Group at Supine & Prone Period [12.20 ±0.71 &12.53 ±0.68] and these differences in the P Mean values between 2 groups at Supine & Prone period was statistically significant at $p<0.001$ & $p=0.01$ respectively.

The meta-analysis that compared PCV and VCV modes during laparoscopic surgery by Wang et al. (2015)[3] concluded that patients had PCV mode had lower P-peak and resistance accompanying higher compliance and P-mean levels. Although with sub group analysis revealed the same results including morbid obese patients who underwent different kind of operations.

Jo et al (2012) found lower P-peak levels during PCV in both supine and prone positions when compared with VCV. Kim et al. (2014) compared the PCV and VCV modes during prone position in high-level spinal cord injury patients and found that P-peak increased after prone positioning in both groups, but this increase was significantly higher in VCV group compared with PCV group. Compliance levels in prone position were found to be statistically higher in PCV group[7]

Tyagi et al.[9] (2011) have observed lower P-peak values and higher compliance without any changes in PaO_2 values; Gupta et al[10] (2012) also reported lower P-peak levels and dead space with higher PaO_2 in the PCV mode. In the Balick- Weber study, (2007) 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.

The lower P-peak levels during the PCV mode have been associated most frequently with in cases of acute lung injury, acute respiratory distress syndrome, and ventilation of the single lung. Observation of higher PaO_2 levels in the PCV mode despite the application of equal tidal volume in both the PCV and the VCV group of patients may be associated with the higher plateau and mean airway pressure recordings. However, higher oxygenation has been observed in some studies despite lack of significant differences in the airway pressure values. The improved oxygenation in the PCV mode may be attributed to ventilation with a higher flow rate and square wave pressure. The elevated flow at the beginning of inspiration causes faster rise in the pressure compared to the VCV mode and the earlier supply of a higher proportion of the tidal volume. The fast alveoli with a short time constant may be overinflated at the start of the inspiration, but the subsequent homogenization of the tidal volume spread in the alveoli prevents the incidence of the development of atelectasis. Also, despite the lowering of the inspiratory flow rate during the plateau pressure phase, the flow never reaches zero as in the VCV (Abdullah et al. 2014)[8]. The better oxygenation may be related to these properties of the PCV.

The mean Cortisol level at Pre-op period in VCV Group was 12.08 ± 1.06 & PCV Group was 12.05 ± 1.03. However, there was no significant difference observed between 2 groups. At Prone & Post-op period, the mean Cortisol levels of PCV Group was significantly lesser [23.74 ± 2.41& 25.62 ± 3.34] as compared to VCV Group [24.90 ± 2.16&27.52± 2.11] and these differences in the mean Cortisol levels between 2 groups were statistically significant at $p=0.04$& $p=0.01$ respectively.

The lower cortisol levels with PCV mode usage may be due to the deceleration flow form, lower P-peak, higher oxygenation and higher compliance levels which may result in lower incidence of atelectasis and pulmonary strain.

The mean glucose levels at Pre-op period in VCV Group was 91.70 +/-

5.90 & PCV Group was 92.70±5.91. However, there was no significant difference observed between 2 groups.At Prone & Post-op period, the mean glucose levels of PCV Group was significantly lesser [110.30±7.80&124.37±7.12] as compared to VCV Group [115.30±7.83&128.43±5.99] and these differences in the mean glucose levels between 2 groups were statistically significant at p=0.04& p=0.01 respectively.

In the study done by Sen et al;[4] showed that as regards the systemic stress responses, the higher postoperative glucose levels of Group VC were, again, within the physiological range. The cortisol and insulin levels were both lowered postoperatively in Group PC in that study. These results supported our study results. The lower systemic stress response and lung injury after PCV mode usage may be due to low peak pressure, high oxygenation and compliance results lower incidence of atelectasis

The mean lactate levels at Pre-op period in VCV Group was 2.58+/-0.38 & PCV Group was 2.58 ±0.40. However, there was no significant difference observed between 2 groups. At Prone & Post-op period, the mean lactate levels of PCV Group was significantly lesser [2.77±0.31&2.84±0.35] as compared to VCV Group [2.97±0.37 &3.03±0.37] and these differences in the mean lactate levels between 2 groups were statistically significant at p=0.04& p=0.01 respectively.

CONCLUSION

The advantages of PCV is that variable gas distribution, efficient tidal volume delivery and high and decelerating inspiratory flow have been showed to compensate for any potential reduction in ventilation caused by pressure limitation. More over the limitation of pressure levels may well have a positive effect on the patient's haemodynamics and might reduce the risk of barotrauma.

We found that, when compared to VCV mode, PCV mode is associated with lower P-peak, P-plateau and higher p mean levels during both supine and prone positions, better oxygenation postoperatively. Both ventilation modes affected the hemodynamics similarly.

Lower blood glucose, lactate and cortisol levels during surgery in prone position and in the early postoperative period in the PCV mode. Hence, PCV mode is better compared to VCV mode in patients undergoing general anaesthesia with endotracheal intubation with controlled ventilation in prone position.

We concluded that when compared with VCV mode, PCV mode is associated with lower P- peak, p mean and P-plateau levels during prone positions, better oxygenation postoperatively, lower blood cortisol, blood glucose and blood lactate levels during surgery in prone position and in the early postoperative period. Hence, PCV mode is better compared to VCV mode in patients undergoing general anaesthesia with endotracheal intubation with controlled ventilation in prone position.

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