Original Research Article

Impact of Pressure Control Ventilation and Volume Control Ventilation on oxygenation, pulmonary mechanics and haemodynamics during One Lung Ventilation in patients undergoing thoracic surgery: Arandomised controlled crossover study

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Abstract

Backgroud: Anaesthesia for thoracic surgery is nowadays performed with one lung ventilation (OLV) using volume control ventilation (VCV). Mechanical characteristics of pressure control ventilation (PCV) are thought to allow more homogenous distribution and improve oxygenation and reduce airway pressure so decrease chances of airway trauma and acute lung injury (ALI). This study was aimed to evaluate impact of two lung ventilation strategy (PCV/VCV) on oxygenation, pulmonary mechanics and haemodynamics during one lung ventilation in patient undergoing thoracic surgery.**Method**: After institutional ethical committee clearance this randomised single blind crossover study includes 30 patients of ASA I,II,III for elective thoracic surgery, using OLV and minimum duration of surgery of one hour were included in this study. Divided in two groups A and B using VCV first then PCV and vice versa. Haemodynamic parameters, ABG analysis and respiratory parameters were recorded**,** data collected and analysed by IBM SPSS statistics version 20.**Results:** Demographic, haemodynamic and ABG parameters were comparable in both groups higher Ppeak during VCV than PCV (p=0.004). Ppeak during OLV with VCV was significantly higher than during two lung ventilation (TLV) before starting OLV and end of the study (p<0.05). Higher dynamic compliance in OLV – PCV group than OLV – VCV group (p<0.001). **Conclusion:** PCV s a better ventilation mode than VCV in OLV with respect to reducing the incidence of barotrauma and ALI in patient undergoing elective thoracic surgery. Both modes are equivalent with respect to arterial oxygenation.

Keywords: One lung ventilation, PCV, VCV.

Introduction

In the modern era thoracic surgeries are performed routinely. These surgeries have many challenges for management of anaesthesia. Using one lung ventilation however solving some conditions to an extent but it is also associated with some challenges like impairment in gaseous exchange leading to arterial hypoxemia, acute lung injury in particularly with previous unhealthy lungs[1].

In most operating theatres Volume Control Ventilation(VCV) is commonly used as mode of ventilation but a constant flow may result in high peak inspiratory pressure increase incidence of barotrauma and uneven distribution of gases. The mechanical characters of Pressure Control Ventilation(PCV) high initial flow initially and decelerating inspiratory flow delivery are thought to allow more homogenous distribution of ventilation and improved perfusion matching[2] also the use of PCV during One Lung Ventilation(OLV) was found to reduce intrapulmonary shunt and peak airway pressure thus limiting risk of barotraumas[3], maintains the uniform distribution of Pulmonary gas and improving oxygenation [4].Main aim of this study was to evaluate the impact of two currently used protective lung ventilation(PCV/VCV) on oxygenation pulmonary mechanics and haemodynamics during OLV in patient undergoing thoracic surgery.

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Materials and Method

This hospital based, randomised, single blind, comparable crossover study included 30 patients of ASA grade I II,III age of 18 to 60 years of either sex, undergoing elective thoracic surgery having minimum duration of one hour requiring OLV for general anaesthesia (GA). Weight of the patients ranged between 40 to 70 kg. Written and informed consent was obtained after through pre anaesthetic evaluation.Exclusion criteria was patients with uncompensated cardiac, hepatic, renal disease, anaemia, ASA grade IV, V , allergic to anaesthetic agents, psychiatric patients, inability to maintain stable mechanical ventilator setting for 30 minutes on OLV and patient with Mallampati grade [3,4]. After taking approval from institutional ethical committee, 30 patients who fulfilled the inclusion criteria were randomised using pre sealed opaque envelope prepared and drawn by independent observer into two groups – A using VCV first then PCV and B using PCV first then VCV. On arrival of patient in operation theatre (OT),the fasting status , consent, Pre Anaesthetic Checkup were checked. Baseline parameters heart rate (HR), Systolic Blood Pressure (SBP),Diastolic Blood Pressure (DBP), Mean arterial pressure (MAP), Oxygen Saturation (SpO2) and baseline arterial blood gas analysis were taken. Intravenous line with 18G/20G cannula were secured. Arterial line under local anaesthesia was secured. Ringer lactate drip was started at rate of 5ml/Kg/hr.

Premedication

All patients received Inj. Glycopyrrolate (0.004 mg/kg i.v.), Inj. Fentanyl citrate (2µg/kg i.v.) and Inj. Midazolam (0.02 mg/kg i.v.) as premedication ten minutes prior to induction of anaesthesia. Preoxygenation with 100% oxygen was done for 5 minutes before starting induction of anesthesia.

Induction

Inj. Propofol 2mg/kg was injected slowly IV over 1 minute, followed by Inj. Succinylcholine 2mg/kg. Patient was given Intermittent Positive Pressure Ventilation (IPPV) with face mask with 100% oxygen for 1 minute.

Intubation was done with Double lumen tube (DLT) of appropriate size (37 F for females and 39 F for males) after direct laryngoscopy. Proper positioning of DLT was checked by chest auscultation before and after turning the patient to the lateral decubitus position

Maintenance was done with InjPropofol (100 µg/kg/min), Inj Fentanyl citrate (0.5 µg/kg at 30 min intervals) and 100% O_2. Muscle relaxation was provided by Inj. Atracurium 0.5 mg/kg i.v. bolus followed by maintenance dose of 0.1 mg/kg intermittently. No volatile anaesthetics were used.

Blease 900 series ventilator (Spacelabs Healthcare, USA) was used to ventilate the patients .After initial two lung ventilation(TLV) with VCV, patients divided in two groups .Patient according to group allocated received VCV first then PCV and vice versa. In both the groups, during VCV the tidal volume was set at 8ml/kg, whereas during PCV the ventilator was adjusted such that the preset pressure attained a tidal volume of 8ml/kg. The end inspiratory pause time was adjusted to 20% and was left unchanged throughout the study period. The initial respiratory rate was set at 12 breaths per minute.

The ratio of inspiration to expiration was 1:2 and FiO2 was 1.0 in both groups. Positive end expiratory pressure (PEEP) of 5cmH_2O was applied to both groups. Variations in tidal volume and respiratory rate were done as per algorithm given below to maintain normocapnia ($EtCO_2$ between 25 to 35 mm Hg).

Intraoperative monitoring was continued.

Haemodynamic parameters, ABG analysis and respiratory parameters were measured and recorded at four stages:

- During TLV using VCV prior the beginning of OLV;
- During OLV 30 min after initiation of the first ventilator mode;
- During OLV 30 min after the second ventilator mode;
- End of study 30 min after re-establishing TLV with VCV.

During the measurement period surgical manipulation of the lung was not allowed.

Respiratory parameters like respiratory rate, inspiratory tidal volume, expiratory tidal volume, minute ventilation, peak airway pressure and mean airway pressure were noted down from the ventilator screen.

Since the dynamic compliance and static compliance were not displayed on Blease ventilator screen and were calculated by formula. Blood was collected from radial artery cannula for ABG analysis. GEM Premier 3000 blood gas analyzer was used.

At the end of surgery, reversal was done with i.v. Inj. Neostigmine (0.05 mg/kg) and Inj. Glycopyrrolate (0.01 mg/kg) only after onset of spontaneous respiration. Patient was transferred to recovery room after extubation or shifted to ICU after exchanging DLT with single lumen ET tube.

Outcome analysis: Data obtained from predesigned proforma was entered into MS EXCEL sheets and thus master chart was prepared. IBM SPSS Statistics Version 20 and Primer was used for statistical analysis. Chi square test was used to analyze qualitative data. Haemodynamic Parameters, Blood Gas Parameters and Respiratory parameters of the patients (Quantitative Data) were expressed in form of Mean ± Standard Deviation. Student's t test and ANOVA were used to determine mean difference between the groups. Tukey's Post Hoc Analysis was performed after ANOVA test. P value less than 0.05 was considered statistically significant.

Results

Both the groups were comparable with regard to age, sex, height and weight.

Haemodynamics

There was no statistically significant difference in heart rate, systolic blood pressure, diastolic blood pressure and mean arterial pressure during OLV with PCV and VCV.(Table 1)

Table 1: Comparison of haemodynamic parameters

Parameter	Baseline TLV		Groups				End of Study		P Value*	Difference*
			VCV		PCV					
	Mean	S.D.	Mean	S.D.	Mean	S.D.	MEAN	S.D.		
Heart Rate(beats/min)	94.77	18.69	91.9	19.66	92.37	19.47	92.33	17.16	0.926	Non Significant
SBP(mmHg)	128.17	10.59	125.23	8.96	121.77	10.22	122.87	8.05	0.168	Non Significant
DBP(mmHg)	74.67	11.24	68.34	12.06	68.33	10.95	68.80	11.15	0.996	Non Significant
MAP(mmHg)	92.50	8.76	87.30	8.81	86.14	7.71	86.82	8.21	0.589	Non Significant

*between VCV and PCV

Arterial blood gases: The PaO_2 (mmHg), $PaCO_2$ (mmHg),pH, SpO_2, standard bicarbonate levels and Alveolar arterial O_2 difference at the end of OLV with PCV and VCV were comparable between the two modes.(Table 2)

Table 2: **Comparison of Arterial Blood Gas Parameters**

Parameter	Baseline TLV		Groups				End of Study		P Value*	Difference*
			VCV		PCV					
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.		
PaO_2 (mm Hg)	333.88	87.45	220.19	92.99	228.52	106.57	307.03	86.83	0.748	Non Significant
$PaCO_2$ (mm Hg)	40.32	7.65	41.82	6.10	40.83	9.07	42.70	8.07	0.620	Non Significant
A-a O_2 Difference (mm Hg)	328.72	90.67	440.53	92.22	433.44	103.50	352.59	86.17	0.780	Non Significant
HCO_3 (mmol/L)	22.26	4.33	22.38	2.71	21.5	3.55	23.26	2.83	0.284	Non Significant
pH	7.36	0.07	7.35	0.07	7.33	0.08	7.35	0.07	0.576	Non Significant
SpO_2 (%)	99.75	0.39	98.96	1.67	98.66	2.07	99.65	0.52	0.539	Non Significant

*between VCV and PCV

Airway pressures

There was a statistically significant lower Peak Inspiratory Pressure (cmH_2O) during PCV than VCV. There was no statistically significant difference in the Plateau Inspiratory Pressure and Mean Airway Pressure (cmH_2O).(Figure1)

Compliance

Dynamic compliance during OLV was found to be significantly higher with PCV than VCV**.** There was no statistically significant difference between the two groups in terms of static compliance. (Figure1) There was no statistically significant difference between

PCV and VCV in end tidal CO_2, minute ventilation, inspiratory tidal volume, expiratory tidal volume and respiratory rate.

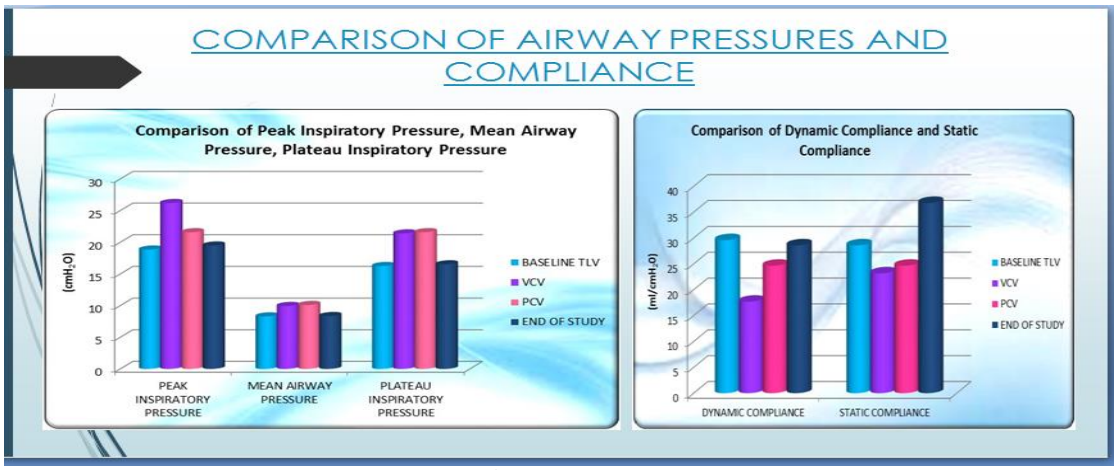

Fig 1:Comparison of airway pressures and compliance

Discussion

There was no statistically significant difference in age , sex, weight and height of the patients in both the groups.In our study, no statistically significant difference was found in the heart rate during 30 minutes of VCV and PCV (p value > 0.05).There was no significant rise in heart rate after beginning OLV with either VCV or PCV. Similar results were obtained by Unzueta *et al[5]* and Montes *et al* [6]while comparing PCV and VCV during OLV.The SBP,DBP and MAP were comparable during OLV with VCV and PCV. These results are consistent with the findings of Tugrul *et al*[7], Unzueta *et al* [5] and Montes *et al*[6] they conducted studies comparing PCV and VCV during OLV.(Table 1)PCV is suggested as a rational method of ventilation during OLV to ensure oxygenation while minimizing peak airway pressure[8]. However, the literature concerning the comparative effects of PCV and VCV on intra operative arterial oxygenation during OLV has produced inconsistent results. The results of this study were that PCV provides no benefit for arterial oxygenation during OLV compared to VCV (p=0.75). Our results are consistent with those of Unzueta *et al*[5] and Montes *et al*[6].

In a study by Jing Cang *et al*[9] on PCV versus VCV during OLV for video assisted thoracoscopic lobectomy , he concluded that VCV had the same performance on intraoperative oxygenation and post operative complications as PCV.In our study, there was no statistically significant difference between the two groups in other arterial blood gas parameters like pH (p=0.57), and Standard bicarbonate levels (p=0.28). This was in correlation with many earlier studies. Unzueta *et al*[5] compared PCV and VCV during one lung ventilation and did not find any significant difference in arterial blood gas parameters between the two modes. Similar findings were observed by P.Cadi *et al*[10], A.Tyagi *et al*[11] and Gupta *et al*[12] during laparoscopic surgeries.

Our results contrast with those of Tugrul *et al*[7] who, in a cross-over trial of 48 thoracic surgical patients, found that PCV resulted in improved oxygenation during OLV compared with VCV in patients undergoing thoracotomy using a V_T of 10 mL/kg during TLV and OLV. The improvement in arterial oxygenation by PCV was not related to variations in mean airway pressure but resulted mainly from the beneficial effects of the decelerating inspiratory flow pattern produced by PCV on the distribution of gas within lungs[13,14]. In diseased lungs with different time constants, the decelerating flow of PCV sustains alveolar pressure longer than constant flow of VCV, thereby improving homogenous distribution inspired gas. However these findings were more relevant in subjects who had poor preoperative lung function. In our study we have selected all the patients with normal preoperative lung functions which can be the reason that difference in PaO_2 in two modes of ventilation was not observed. (Table 2)We found that the partial pressure of arterial CO_2 ($PaCO_2$) at the end of OLV with VCV was comparable to $PaCO_2$ at the end of OLV with PCV (p=0.62). This was similar to findings of Tugrul *et al*[7] while comparing the two modes during OLV. These findings are also similar to earlier studies done for comparing PCV and VCV during laparoscopic cholecystectomy by Elvira Martizez Leyra *et al*[15] and A.Tyagi *et al*[11] who showed that the $PaCO_2$ levels between the two modes were comparable both before and after pneumo peritoneum.(Table 2)

There was no significant difference in the Alveolar arterial O_2 gradient after OLV with PCV and VCV in our study (p=0.78). The Alveolar arterial O_2 gradient was significantly higher after OLV (with PCV or VCV) than after TLV before starting OLV and TLV at the end of study. This was similar to the findings observed by Montes *et al*[6] while comparing the two modes during OLV.(Table 2)

In our study we found a significantly higher P_{peak} during VCV than PCV (p=0.004). P_{peak} during OLV with VCV was significantly higher than during two lung ventilation before starting OLV and at the end of study (p<0.05). P_{peak} during OLV with PCV was higher than TLV but statistically not significant.(Figure 1). Our results are consistent with those of Heimberg C *et al*[16]who compared PCV and VCV in patients undergoing thoracotomy and OLV for cardiovascular disease and observed that PCV showed significantly lower P_{peak} than VCV. Prella *et al*[1] also observed that PCV allows generation of lower P_{peak} through precise titration of lung distending pressure while comparing PCV and VCV in patients with ALI/ARDS.

End inspiratory plateau pressure is seen as a more important determinant of barotrauma than peak airway pressure[18].In our study no significant difference was found between plateau pressure (p = 0.68) as well as the mean airway pressure (p=0.89) during VCV and PCV. $P_{plateau}$ and P_{mean} were significantly higher during OLV than TLV. This was similar to the findings of Pardos PC *et al*[19].

In our study, we found higher Dynamic compliance in OLV-PCV group when compared to OLV-VCV group (p<0.001) due to lower Peak inspiratory pressure recorded during PCV. Whereas there was no statistically significant difference in Static compliance in both the groups (p=0.51) because of comparable plateau pressure (Figure 1) .Our results are similar to Balick Webber *et al*[20] who demonstrated that dynamic compliance was significantly higher in PCV than VCV in patients undergoing laparoscopy. The higher dynamic compliance was of interest here because it was associated with a change in gas

distribution[21] although we did not observe a higher PaO_2 which could support the above statement in our study. In a study by Jianli Li et al[22] on PCV–VG(volume guaranteed) mode combined with an open lung approach(OLA), they found significant reduction in P mean at different time interval. They also observed preferable levels of dynamic compliance,PaO2/FiO2 ratio and appropriate levels of neurofibroela stage. However there was no difference in haemodynamics. As high Pmean especially mean alveolar pressure increases pulmonary vascular resistance and makes blood flow towards non ventilated lung thus leading to disturbance in Qs/Qt. They found superior Qs/Qt in PCV plus OLA than other groups.

In our study the minute ventilation requirement to maintain normocarbia (i.e. $EtCO_2$ between 25 and 35mm Hg) was statistically similar between the two ventilator modes (p=0.88). No significant difference was seen in the Inspiratory tidal volume (p=0.92), Expiratory tidal volume (p=0.72) and Respiratory Rate (p=1.0) during VCV or PCV.

Conclusion

Pressure controlled ventilation showed lower peak airway pressures and higher dynamic compliance when compared with volume controlled ventilation. Pressure controlled ventilation however did not result in any significant improvement in arterial oxygen tension as compared to volume controlled ventilation so we concluded that Pressure controlled ventilation is a better ventilation mode than Volume control ventilation during one lung anaesthesia with respect to reducing the incidence of barotrauma and acute lung injury in patients undergoing elective thoracic surgery. Both modes are equivalent with respect to arterial oxygenation.

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