

Comparison of volume control and pressure control ventilation in patients undergoing single level anterior cervical discectomy and fusion surgery

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ABSTRACT

Background and Aims: Pressure control and volume control ventilation are the most preferred modes of ventilator techniques available in the intraoperative period. The study compared the intraoperative ventilator and blood gas variables of volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV) in patients undergoing single level anterior cervical discectomy and fusion (ACDF). **Methods:** After obtaining Institutional Ethical Committee approval and informed consent, sixty patients scheduled for single level ACDF surgery performed in supine position under general anaesthesia were included. Group V (30 patients) received VCV and Group P (30 patients) received PCV. The primary objective was oxygenation variable $\text{PaO}_2/\text{FiO}_2$ at different points of time i.e. T1–20 min after the institution of the ventilation, T2–20 min after placement of the retractors and T3–20 min after removal of the retractors. The secondary objectives include other arterial blood gas parameters, respiratory and haemodynamic parameters. NCSS version 9 statistical software was used for statistics. Two-way repeated measures for analysis of variance with *post hoc* Tukey Kramer test was used to analyse continuous variables for both intra- and inter-group comparisons, paired sample *t*-test for overall comparison and Chi-square test for categorical data. **Results:** The primary variable $\text{PaO}_2/\text{FiO}_2$ was comparable in both groups ($P = 0.08$). The respiratory variables, PAP and C_{dynam} were statistically significant in PCV group compared to VCV ($P < 0.05$), though clinically insignificant. Other secondary variables were comparable. ($P > 0.05$) **Conclusion:** Clinically, both PCV and VCV group appear to be equally suited ventilator techniques for anterior cervical spine surgery patients.

Key words: Anaesthesia, cervical, discectomy, mechanical, surgery, ventilation

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INTRODUCTION

Volume-controlled ventilation (VCV) is commonly used for ventilation in the intraoperative period. The traditional approach of VCV during cervical spine surgery in supine position may result in an increase in peak airway pressure (PAP) and plateau pressure (P_{plat}) due to continuous retraction of airway structures in the intraoperative period. Any change in compliance or resistance with VCV results in an increase in pressure generated within the lungs. This may present with volutrauma or barotrauma. These continual changes may sometimes result in delayed extubation and other respiratory complications such as bronchospasm,

atelectasis in the post-operative period. The other mode of ventilation which limits the airway pressure and is available in the current anaesthesia work stations is the pressure controlled ventilation (PCV).

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The decelerating inspiratory flow used during PCV generates high initial flow rate, causing more rapid alveolar inflation. This mechanical effect of PCV allows a homogeneous distribution of ventilation leading to better ventilation-perfusion (V/Q) matching. At the same time, pressure limits and uniform distribution of forces within the lung reduce the risk of volu- and baro-traumas.^[1,2] On the other hand, PCV has its own limitations such as hypoventilation, hypoxia and hypercarbia associated with the inadequate transfer of ventilation pressure to the lung in the presence of external compression of the endotracheal tube or upper airway.^[3] This study aims to compare the currently available techniques for ventilation in patients undergoing cervical spine surgery in supine position.

The null hypothesis for this study aims at the comparable efficacy of VCV and PCV for intraoperative ventilation in patients undergoing single level anterior cervical discectomy and fusion (ACDF). The alternative hypothesis states that PCV is advantageous over VCV.

METHODS

After obtaining Institutional Ethical Committee approval and informed consent, 60 American Society of Anesthesiologists' (ASA) I-II patients scheduled for single level ACDF under GA performed in supine position were included in the study. All the patients were randomly allocated equally into two groups – Group VCV and Group PCV using RAND (0, 1) (Microsoft [2010]. Microsoft Excel [computer software] Redmond, Washington). The inclusion criteria included ASA I and ASA II patients, age - 18–60 years of either sex or pre-operative baseline PaO₂ >70 mmHg and PCO₂ around 35–45 mmHg on room air. Patients with pre-operative endotracheal tube *in situ*, coexisting chronic bronchopulmonary disease, and redo surgery were excluded from the study. Post-inclusion exclusion criteria included severe haemodynamic instability in the intraoperative period, suspicion of intraoperative venous air embolism, decision taken intraoperatively for two level procedures and or corpectomy, duration exceeding >3 h, patients not fulfilling the criteria of ventilator settings in both VCV and PCV group patients.

A complete pre-anaesthetic evaluation was done. This included measurement of breath holding time (BHT) and peak expiratory flow rate (PEFR). In the

operating room, a peripheral venous access and an arterial access were secured under local anaesthesia and a baseline arterial blood gas (ABG) was drawn for analysis before induction. Routine continuous monitoring with heart rate (HR), blood pressure (BP), SpO₂, respiratory rate (RR), capnometry, temperature and electrocardiogram was carried out throughout the procedure. Standard anaesthesia procedure was followed in both groups. The pre-operative readings, as well as the readings in intraoperative period, were recorded: T0 – baseline (on room air), T1 – 20 min after the institution of type of ventilation as per randomisation protocol, T2 – 20 min after placement of the retractors and finally T3 – 20 min after removal of the retractor. A standard protocol for general endotracheal anaesthesia with controlled ventilation was conducted in all 60 patients. The trachea was orally intubated with a polyvinyl chloride-cuffed endotracheal tube of appropriate size after achieving adequate relaxation with injection atracurium 0.6 mg/kg. The lungs were ventilated with 50% air, 50% oxygen and isoflurane 0.6%–1%. Muscle relaxation was maintained with injection atracurium infusion 5–6 µg/kg/min with continuous train-of-four monitoring. Entropy was used to monitor the level of anaesthesia (entropy maintained between 50 and 60). Injection fentanyl 0.5 µg/kg was administered for additional perioperative analgesia.

The available S/5 Aespire 7100 (Datex-Ohmeda, GE Healthcare, Madison, USA) anaesthesia work station was used for intraoperative ventilation in both groups. In Group VCV, ventilation was started with a tidal volume (V_T) of 8 mL/kg and positive end expiratory pressure (PEEP) of 5 cm H₂O. The initial V_T was increased by 1 mL/kg every 5 min until 12 mL/kg, and the RR was increased by 2/min every 5 min till 20/min to maintain end-tidal carbon dioxide (EtCO₂) between 35 and 40 mmHg. Patients in Group VCV were dropped from the study when EtCO₂ was not maintained with V_T of 12 mL/kg and RR of 20/min. Following fall in EtCO₂ <35 mmHg, RR was decreased by 2/min every 5 min till 8/min, with a decrease in V_T of 1 mL/kg until 6 mL/kg. Patients developing abnormally sudden increase in PAP >30 cmH₂O and not maintaining SpO₂ ≥95% with the above manoeuvres were also excluded from the study [Figure 1].

In Group PCV, the peak inspiratory pressure (PIP) not exceeding 30 cmH₂O was set to provide a V_T of 8 mL/kg. RR was adjusted to keep an EtCO₂ of 35–40 mmHg.

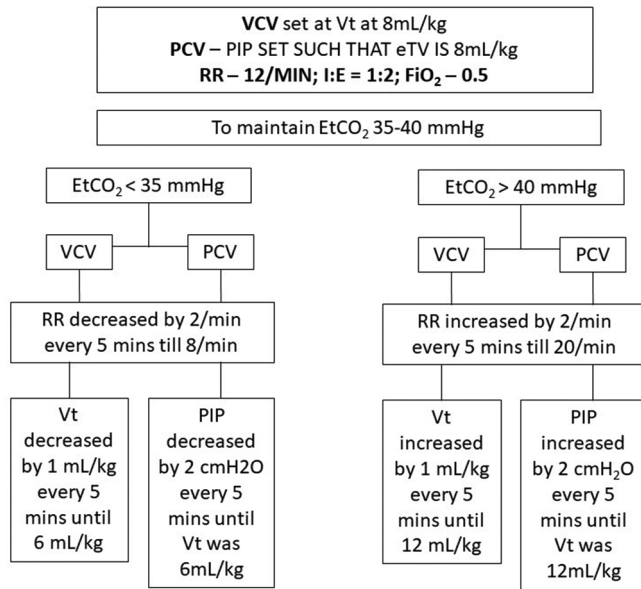


Figure 1: Flow charts for volume controlled ventilation and pressure controlled ventilation settings. VCV – Volume controlled ventilation; PCV – Pressure controlled ventilation; Vt – Tidal volume; PIP – Peak inspiratory pressure; RR – Respiratory rate; I:E – Inspiration:Expiration; FiO_2 – Inspiratory oxygen concentration; $EtCO_2$ – End tidal carbon dioxide

Following an increase in $EtCO_2$, the RR was increased by 2/min every 5 min till 20/min, achieving the target $EtCO_2$. Following a fall in $EtCO_2 < 35$ mmHg, the RR was decreased by 2/min every 5 min till 8/min, with a decrease in PIP by 2 cmH_2O every 5 min until 30 cmH_2O . Patients in PCV requiring PIP > 30 cmH_2O and RR > 20 /min to maintain normocarbia were then shifted to VCV and were dropped from the study [Figure 1].

Variables measured at different points of time include PAP, mean airway pressure (P_{mean}), P_{plat} and ABG findings (PaO_2/FiO_2 , PaO_2 , PAO_2 , $P(a-A) O_2$ and $PaCO_2$). The $P(a-ET) CO_2$ was calculated as the difference between arterial and $EtCO_2$ partial pressures obtained simultaneously. Blood pressure (BP) was continuously measured from the radial artery catheter. Other variables measured were $EtCO_2$, mean arterial pressure, HR, SpO_2 , V_T , RR and inspiration:expiration (I:E) ratio. Static compliance (C_{stat}), dynamic compliance (C_{dynam}), oxygenation index and dead space ventilation (V_D/V_T) are derived parameters. C_{stat} is derived from the formula: $V_T/P_{plat} - PEEP$ and C_{dynam} from $V_T/PAP - PEEP$. Oxygenation index is measured from the formula: $FiO_2/PaO_2 \times P_{mean}$ and V_D/V_T is calculated from the formula: $P(a-ET) CO_2/PaCO_2$. PAO_2 was derived from the equation: $FiO_2(P_{ATM} - pH_2O) - PaCO_2/RER$ where RER is the respiratory exchange ratio and its value is 0.8. Neuromuscular blockade was reversed

with injection neostigmine 0.05 mg/kg and injection glycopyrrolate 0.01 mg/kg when the train-of-four ratio was \geq two twitches. The patients were extubated after fulfilling the criteria of adequate reversal. The primary objectives of this study were to evaluate and compare the intraoperative blood gas variable, PaO_2/FiO_2 of VCV and PCV in patients undergoing single level ACDF under general anaesthesia (GA). The secondary objectives include other blood gas, respiratory, ventilator and haemodynamic variables at different time points.

G power version 3.1.9.2 (Universität Düsseldorf, Germany, copyright at 2014) was used for sample size estimation. The sample size for the study was estimated calculated by *a priori* estimation for repeated ANOVA: within and between interactions taking Cohen's effect size F value as 0.25, the correlation between repeated measures as 0.5 and nonsphericity correction ϵ of 1 into consideration. Total sample size of 44 (22 each) was estimated with 95% power and α error of 0.05. As drop out of cases would be expected, a total sample size of 60 (30 in each group) were taken for undertaking this study.

NCSS version 9 statistical software (NCSS, Kaysville, UT, USA) was used for statistical analysis. The continuous data displayed as mean and upper and lower limits of 95% confidence interval of the mean difference ($M \pm UL/LL$ of 95% confidence interval MD) and categorical data as frequency (n) and percentage (%). The values obtained at different points of time were obtained. Normal distribution of the data was ascertained by Anderson-Darling test and variance imbalance by Levene's test. As the data distribution was found to be normal with normal variance, two-way repeated ANOVA was used to analyse continuous variables for both intra- and inter-group comparisons, paired sample t -test for overall comparison and Chi-square test for categorical data. $P < 0.05$ was considered statistically significant.

RESULTS

The data were found to be normally distributed with equal variance in both groups. All the patients adhered to/trailed the inclusion criteria and no patients were excluded from the study. The demographic profile and other characteristics such as duration of anaesthesia, baseline BHT and PEFr were comparable in both groups [Table 1]. The measures of intraoperative ventilation and respiratory variables in both groups at

Table 1: Demographic profile and other baseline characteristics

Demographic Parameters	VCV (n=30)	PCV (n=30)	Probability value (P)
Age (years)	43.53 (12.87) (21-65)	43.46 (12.64) (20-60)	0.98
Gender (male/female)	23/7 (76.7/23.3)	25/5 (83.3/16.7)	0.5
BMI (kg/m ²)	26.13 (2.9) (21.4-31.4)	25.10 (3.2) (19.5-35)	0.2
ASA (I/II/III)	26/4/0 (86.7/13.1/0)	28/2/0 (93.3/6.7/0)	0.4
Diabetes	2 (6.7)	1 (3.3)	0.55
Hypertension	3 (10)	3 (10)	1
BHT (s)	20.7 (3.9) (14-32)	21.5 (4.5) (15-30)	0.43
PEFR (mL)	214.3 (56) (120-310)	212 (70.8) (120-350)	0.89
Baseline PaO ₂ (mmHg)	90.1 (7.5) (87.3-92.9)	88.5 (7.9) (85.5-91.4)	0.4
Duration of anaesthesia (min)	190 (44.7) (120-300)	173 (39.14) (120-240)	0.12

VCV – Volume control ventilation; PCV – pressure control ventilation; n – Number of patients; BMI – body mass index; ASA – American Society of Anesthesiologists; BHT – Breath holding time; PEFR – Peak expiratory flow rate

three points of time, T1, T2 and T3 were depicted in Table 2. The oxygenation variables PaO₂/FiO₂ and PaO₂ were comparable in both groups ($P > 0.05$). Though the Pmean was comparable in both the groups, both PAP ($P = 0.0007$) and C_{dynam} ($P = 0.04$) were significant in both the groups, but values were within the normal clinical range. [Figures 2 and 3]. Though clinically not relevant, both C_{stat} and C_{dynam} after removal of the retractors (T3) was significantly lower compared to the baseline T1 values in the group VCV. ($P = 0.02/0.01$) The (Pa – ET) CO₂ difference was significantly lower in PCV group compared to VCV group ($P = 0.02$), but values were within the normal clinical range. The alveolar oxygenation was 314.4/312 in the VCV and PCV groups respectively ($P = 0.05$) [Figure 3].

Overall, the haemodynamic and metabolic variables were comparable in both groups except HR but still in the clinically normal range. The lactate levels were statistically significant from the control values in both groups but within the clinically normal range [Table 3].

DISCUSSION

Improper retraction of trachea in anterior cervical spine surgery may lead to airway obstruction and further respiratory complications.^[4] Patients who have cervical spine problems can have associated quadriplegia and respiratory muscle weakness, which may further compromise respiratory dynamics.^[5,6] VCV is routinely used in the intraoperative period. PCV has the advantage of limiting the airway pressures and thus increases the C_{dynam} and improves the oxygenation.^[3] This may be advantageous especially in obese patients and with compromised respiratory dynamics. The hypothesis for this study: PCV is advantageous over VCV in maintaining the respiratory and oxygenation parameters.

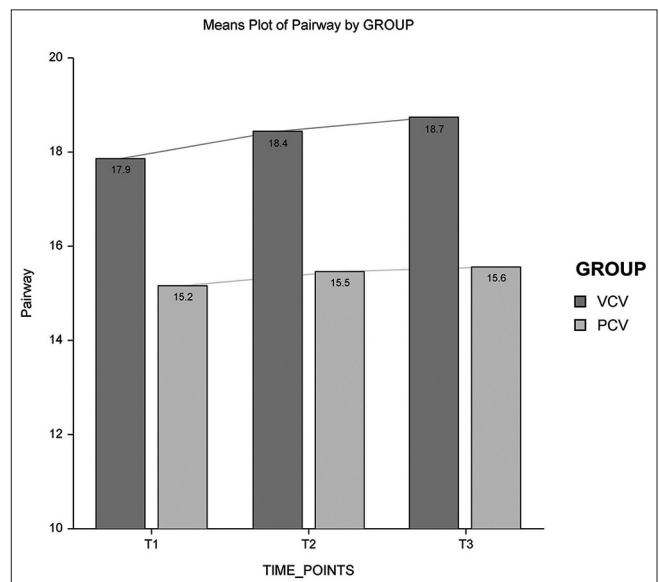


Figure 2: Comparison of peak airway pressure at three-time points in both the groups. VCV – Volume controlled ventilation; PCV – Pressure controlled ventilation; PAP – peak airway pressure; T1-20 min after institution of the ventilator parameters; T2-20 min after placement of the retractors; T3-20 min after removal of the retractors

Literature has shown similar comparative evaluation in patients undergoing laparoscopic cholecystectomy but none with regards to cervical spine surgery.^[7,8] To the best of our knowledge, this is the first report where VCV was compared with PCV with respect to cervical spine patients for their effect on the dynamics in the intraoperative period and post-operative neurosurgical intensive care unit.

Variables associated with post-operative airway complications are an exposure involving more than three vertebral bodies or involving C2, C3, or C4; a blood loss of >300 mL; an operative time >5 H; and combined anteroposterior cervical spine surgery.^[9] The time taken for surgery is proportional to the number of levels involved. Prolonged retraction and increased blood loss may further compromise respiratory

Table 2: Comparison of respiratory variables at different time points and overall in both the groups (by repeated analysis of variance and t-tests)

Respiratory parameters	Time points	Group VCV (mean) (n=30)	Lower 95% CI	Upper 95% CI	P	Group PCV (mean) (n=30)	Lower 95% CI	Upper 95% CI	P
PAP (cm H ₂ O)	T1	17.9				15.2			
	T2	18.4	-3	1.9	0.8	15.5	-0.93	0.3	0.7
	T3	18.7	-3.3	1.6	0.7	15.7	-1.03	0.2	0.45
	Overall	18.3				15.4	-3.2	0.17	0.001
P _{plat} (cm H ₂ O)	T1	16.6							
	T2	17.2	-1.2	0.06	0.1				
	T3	17.2	-1.1	0.1	0.15				
	Overall	17	-0.01	3.2					
Mean airway pressure P _{mean} (cm H ₂ O)	T1	6.8				6.9			
	T2	7	-0.55	0.16	0.6	6.9	-0.5	0.2	0.8
	T3	7	-0.5	0.2	0.9	7.1	-0.45	0.26	1
	Overall	6.8	-0.7	0.39		7	-0.39	0.7	0.6
PaCO ₂ (mmHg)	T1	36.5				35.04			
	T2	33.8	0.9	4.45	0.0002*	36.1	-2.9	0.7	0.5
	T3	35.3	-0.6	3	0.4	35.6	-2.3	1.3	1
	Overall	35.2	-1.45	2.1		35.6	-2.1	1.45	0.7
P(a-ET) CO ₂ (mmHg)	T1	5.02				1.6			
	T2	3	0.3	3.8	0.01*	2.5	2.5	0.8	0.7
	T3	3.4	-0.06	3.4	0.07	2.6	2.6	0.8	0.6
	Overall	3.8	-2.8	-0.28		2.2	0.28	2.8	0.02*
PaO ₂ (mmHg)	T1	231				236.7			
	T2	225.1	-11.4	23.2	0.9	230.8	-11.4	23.2	0.9
	T3	232.7	-18.9	15.6	0.99	230.1	-10.7	23.8	0.9
	Overall	229.6	-19.2	25.1		232.5	-25.1	19.2	0.8
PaO ₂ /FiO ₂	T1	462				473.3			
	T2	450.2	-22.7	46.3	0.9	461.5	-22.8	46.4	0.9
	T3	465.3	-37.9	31.2	0.99	460.3	-21.5	47.6	0.9
	Overall	459.2	-38.4	50.2		465	-50.1	-38.4	0.8
PAO ₂ (mmHg)	T1	314.5				312.7			
	T2	314.6	-2.6	2.4	1	311.3	-1.1	3.9	0.6
	T3	314.1	-2.2	2.8	0.99	312.1	-1.9	3.1	0.98
	Overall	314.4	-4.7	-0.007		312	-0.007	4.7	0.05
Pa/PA O ₂	T1	0.73				0.76			
	T2	0.71	-0.03	0.07	0.9	0.73	-0.04	0.07	0.96
	T3	0.74	-0.06	0.05	0.99	0.71	-0.03	0.07	0.9
	Overall	0.7	-0.05	0.08		0.74	-0.08	0.5	0.7
P(A-a)O ₂ (mmHg)	T1	83.5				76.0			
	T2	89.5	-23.2	11.2	0.9	80.5	-12.7	21.7	0.97
	T3	81.5	-15.2	19.2	0.99	81.9	-18.6	15.8	0.99
	Overall	84.8	-26.7	16.1		79.5	-16.1	26.6	0.6
C _{stat} (mL/cm H ₂ O)	T1	41.8							
	T2	38.6	-0.65	7.03	0.2				
	T3	37.7	0.3	7.9	0.02*				
	Overall	39.3	-5.2	7.5					
C _{dynam} (mL/cm H ₂ O)	T1	37				42			
	T2	34.5	0.05	4.9	0.3	39.7	-1.5	6.2	0.3
	T3	33	1.5	6.4	0.01*	39.8	-1.6	6.1	0.4
	Overall	34.8	-125.5	-98.4		40.5	-7.5	5.2	0.04*
Dead space ventilation (V _D /V _T)	T1	0.09				0.04			
	T2	0.066	-0.02	0.06	0.6	0.07	-0.06	0.06	0.2
	T3	0.08	-0.04	0.04	1	0.09	-0.05	0.02	0.7
	Overall	0.08	-0.05	0.02		0.064	-0.02	0.05	0.4
Oxygenation index (%)	T1	1.6				1.5			
	T2	1.7	-0.3	0.06	0.36	1.6	-0.3	0.08	0.6

Contd...

Respiratory parameters	Time points	Group VCV (mean) (n=30)	Lower 95% CI	Upper 95% CI	P	Group PCV (mean) (n=30)	Lower 95% CI	Upper 95% CI	P
	T3	1.6	-0.2	0.2	1	1.57	-0.24	0.1	0.9
	Overall	1.6	-0.3	0.2		1.6	-0.2	0.3	0.7

VCV – Volume control ventilation; PCV – Pressure control ventilation; n – Number of patients; CI – Confidence intervals; P – Probability; T1 – 20 min after institution of the ventilator parameters; T2 – 20 min after placement of the retractors; T3 – 20 min after removal of the retractors; cm H2O – Centimeters of water; PaCO₂ – Partial pressure of arterial carbon dioxide; P(a-ET) CO₂ – Difference of partial pressure of arterial and end tidal carbon dioxide; VD – Dead space volume; VT – Tidal volume; PaO₂ – Partial pressure of arterial oxygen content; PAO₂ – Partial pressure of alveolar oxygen content; FiO₂ – Fraction of inspired oxygen concentration; PAP – Peak airway pressure; C_{dynam} – Dynamic compliance; C_{stat} – Static compliance

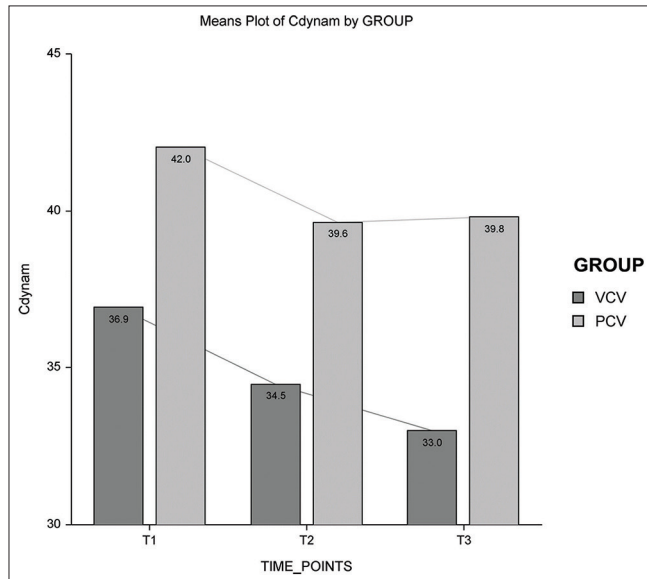


Figure 3: Comparison of dynamic compliance at three-time points in both the groups. VCV – Volume controlled ventilation; PCV – Pressure controlled ventilation; C_{dynam} – Dynamic compliance; T1-20 min after institution of the ventilator parameters; T2-20 min after placement of the retractors; T3-20 min after removal of the retractors

dynamics. Hence, the type of ventilation may play a role in maintaining respiratory dynamics in patients where the duration of surgery is prolonged or with considerable blood loss. Due to this reason, the authors had taken single level surgeries in this study to avoid bias.

The findings of our study displayed significant values of PAP and C_{dynam} in PCV group compared to VCV group when the ventilator was set to deliver the same V_T to maintain a constant EtCO₂ in patients undergoing ACDF. Significant improvement in oxygenation (PaO₂ and PaO₂/FiO₂) and V/Q ratio was reported with PCV compared to VCV in morbidly obese patients undergoing laparoscopic cholecystectomy under GA.^[8] However, this study did not demonstrate any difference in the airway pressures in both groups. In contrast, our study demonstrated a significant decrease in PAP and increase in dynamic compliance in PCV group but the values were within the clinically normal range. There was no significant change in oxygenation index

and V/Q ratio. This study involved adult population within normal BMI, and the site of surgery is in the upper respiratory tract. This may explain the findings of our study. Whereas another study has only shown beneficial effects of PCV in improving oxygenation and alveolar recruitment but also in limiting airway pressures in obese patients undergoing laparoscopic cholecystectomy under GA.^[7]

The type of ventilation, both VCV and PCV has shown controversial results with one lung ventilation (OLV). One study, reported in 2007 has shown comparable effects of PCV and VCV on OLV.^[10] Before that long back in 1997 and later, some recent studies have reported beneficial effects of PCV in OLV.^[11-13] From cardiac point of view, one study has reported an overall improvement in cardiac performance with PCV compared to VCV in patients undergoing OLV.^[14] Further, a recent meta-analysis in 2016 has given indefinite conclusions regarding the benefit of improved oxygenation with PCV apart from a lower PIP.^[15]

Physiological dead space/V_T ratio has shown to be good predictor for success of weaning and extubation, especially in children.^[16] The chances of non-invasive ventilation and extubation failure have shown to increase in patients with increased dead space ventilation. However, our study did not demonstrate any difference in the dead space ventilation with the two ventilator techniques. Literature has reported added beneficial effects of PCV in the light of reduced work of breathing with improved comfort for patients with increased and variable respiratory demand.^[17]

Protective ventilation strategies like PCV are coupled with decreased V_T and lower P_{plat}. At the same time, they are found to be associated with reduced expression of systemic inflammatory mediators.^[18] This would help in reducing the incidence of severity of lung injury. This is a major limitation of our study for we did not measure inflammatory mediators. Rather, lactate levels were slightly elevated in both

Table 3: Comparison of haemodynamic and metabolic parameters in both groups

Parameters	Time points	Group VCV (mean) (n=30)	Lower 95% CI	Upper 95% CI	P	Group PCV (mean) (n=30)	Lower 95% CI	Upper 95% CI	P
HR (/min)	T0	74.7				83.2			
	T1	79	-9.5	0.8	0.16	84.6	-6.4	3.8	0.9
	T2	74.9	-5.3	4.9	1	82.1	-4	6.2	0.99
	T3	77.2	-7.6	2.6	0.8	81.6	-3.5	6.7	0.98
	Overall	76.5	2.3	10.5		82.9	-10.4	-6.4	0.002*
MAP (mmHg)	T0	90.4				95.3			
	T1	90	-7.6	8.3	1	87.4	-0.008	15.9	0.05
	T2	89.6	-7.2	8.7	1	92	-4.7	11.2	0.9
	T3	92	-9.6	6.3	1	90.2	-2.9	13	0.5
	Overall	90.5	-3.6	4.9		91.2	-4.9	3.6	0.7
pH	T1	7.4				7.4			
	T2	7.3	-0.06	0.3	0.4	7.4	-0.14	0.2	1
	T3	7.4	-0.13	0.2	1	7.4	-0.14	0.2	1
	Overall	7.38	-0.04	0.1		7.4	-0.1	0.04	0.4
	Serum lactates (mmol/L)	T1	1.2				1.5		
T2		1.7	-0.8	-0.08	0.007*	1.98	-0.8	0.09	0.006*
T3		1.8	-1.0	-0.2	0*	2.16	-1	-0.3	0*
Overall		1.6	-0.06	0.66		1.9	-0.66	0.06	0.1
Serum HCO ₃ (mmol/L)		T1	22.4				22.8		
	T2	21.8	-0.07	1.9	0.1	22.2	-0.3	1.5	0.3
	T3	22.8	0.5	2.3	0.00004	22	-0.1	1.7	0.1
	Overall	22.4	-0.9	0.7		22.3	-0.7	0.9	0.8

VCV – Volume control ventilation; PCV – Pressure control ventilation; n – Number of patients; T0 – Baseline parameters; T1 – 20 min after institution of the ventilator parameters; T2 – 20 min after placement of the retractors; T3 – 20 min after removal of the retractors; MAP – Mean arterial pressure; HR – Heart rate; pH – Negative algorithm of hydrogen ion concentration; HCO₃ – Bicarbonate; SD – Standard deviation; P – Probability. P < 0.005; this is the overall significance between the two groups

the groups following both modes of ventilation, but within the normal range.

A new mode of ventilation ‘pressure control ventilation with volume generated’ (PCV-VG) has come up in modern anaesthesia ventilators. PCV-VG is actually a variant of PCV (decelerating flow with constant pressure) that changes to a constant flow ventilation (VCV) when the tidal volume during PCV is not likely to reach the target tidal volume. This may replace both VCV and PCV in specially recruited patients where advantages of both VCV and PCV were coupled for better benefits.^[19] A recent study on thoracic surgery has shown beneficial effects of PCV-VG compared to VCV in patients with OLV.^[20] In contrast, comparable results were seen with VCV, PCV and PCV-VG in patients undergoing abdominal surgery.^[21,22]

The haemodynamic and metabolic changes were comparable in both groups except for HR. Though the HR was statistically significant, clinically the value was within normal limits. Rather, the value was higher in PCV group compared to VCV group which was in quite contrast to the haemodynamic changes seen usually with PCV. Hence, this may not be relevant with respect to haemodynamically stable patients.

There are some limitations in our study. They include the inability to measure P_{plat} and C_{stat} in PCV patients, auto-PEEP, inflammatory mediators and non-availability of ventilator graphic displays. In our study, we have recruited only healthy patients without any pulmonary pathology. This was intentionally done to compare the oxygenation, respiratory and haemodynamic indices with both the modes of ventilation in healthy controls undergoing cervical spine surgery. Further study is required to extrapolate these findings in patients with respiratory pathology or obese patients.

The other lacunae in PCV Group patients is that in case the airway resistance increases or lung compliance falls, tidal volume generated is reduced and hypoventilation may result. Hence, one need to be cautious when administering PCV type of ventilation for intraoperative management.

CONCLUSION

Clinically, both PCV and VCV appear to be-equally suited ventilator techniques for anterior cervical spine surgery patients.

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Conflicts of interest

There are no conflicts of interest.

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