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Comparison of Volume Controlled Ventilation with Pressure Controlled Ventilation During Lumbar Spine Surgery in Prone Position: A Randomized Controlled Study

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Abstract

Background: Different modes of mechanical ventilation such as volume controlled ventilation (VCV) and Pressure Controlled Ventilation (PCV) are deployed to balance respiratory mechanics, gas exchange and hemodynamics in patients undergoing lumbar spine surgeries in prone position. *Methods:* This prospective study included 72 patients undergoing lumbar spine surgeries in prone position. They were randomized to two Groups – Group V (who received volume controlled ventilation) and Group P (who received pressure controlled ventilation). The ventilation and hemodynamic parameters were statistically analyzed at 5 min after intubation in supine (S5), 60 min after prone (P60) and 180 min after prone (P180) position. Oxygenation parameters were assessed from ABG in supine (baseline) and at the end of surgery in prone position. Chi-square, independent *t*-test and ANOVA were used to compare the data between the two groups. *Results:* Demographics, oxygenation and hemodynamics were comparable between the two groups. P peak and P mean increased from supine to prone position in both the groups. The P peak in VCV was higher than PCV in prone position and the difference was significant at first hour [$p = 0.008$] . The dynamic compliance (Cdyn) decreased in both PCV and VCV from supine to prone position. There was significant increase in Cdyn in PCV at the end of first hour in prone position ($p = 0.005$). Vte, MV, PEEP, RR, $EtCO_2$ and V_D/V_T did not show any significant difference between the groups ($p > 0.05$). *Conclusion:* Both VCV and PCV can be safely used to ventilate patients in prone position undergoing lumbar spine surgeries.

Keywords: Prone position; Mechanical ventilation; Volume controlled ventilation; Pressure controlled ventilation; Hemodynamics.

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Introduction

Prone position is needed for surgical exploration during spine surgeries done by posterior approach. During general anesthesia, changing from supine to prone position may have adverse effects on oxygenation, ventilation and circulation.

Prone position interferes with lung mechanics by decreasing the pulmonary compliance and increasing the airway pressure.[1–3] High airway pressure may in turn impair venous return to heart, decrease cardiac output and increase the systemic venous pressure. High pressure in epidural veins increases surgical bleeding which can be accentuated if patient is improperly positioned.[4]

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In anesthetized patients, different modes of mechanical ventilation such as Volume Controlled Ventilation (VCV) and Pressure Controlled Ventilation (PCV) are deployed to balance respiratory mechanics, gas exchange and hemodynamics. Ventilator induced lung injury could be triggered by volutrauma, atelectrauma and biotrauma. This has been more significant in obese, laparoscopic surgeries, one lung ventilation and specific patient positions.[3,5,6] Very few studies have compared the two Modes – PCV and VCV in surgeries conducted in different positions.[1,7,8] The advantage of PCV over VCV in improvement of oxygenation and ventilation has shown inconsistent results. In our study, primary aim was to compare the effects of PCV with VCV on lung mechanics and gas exchange using ventilation and oxygenation parameters till the end of surgery. Secondary objective was to evaluate the effect of these two modes of ventilation on hemodynamic changes. We hypothesized that the PCV is a superior ventilation mode to VCV in lumbar spine surgeries done in prone position.

Materials and Methods

This prospective, unblinded randomized controlled study was conducted from November 2013 to November 2015 in a tertiary care hospital. The study protocol was approved by the Institutional Review Board (148/2013) and was registered at CTRI.gov.nic.in (CTRI/2018/01/011216).

Seventy two American Society of Anesthesiologists (ASA) Physical Status I and II patients, aged 18–65 years belonging to either sex scheduled for lumbar spine surgeries to be conducted in prone position under General Anesthesia [GA] were included in the study. Patients who were unwilling for study, with Body Mass Index (BMI) > 30, documented autonomic neuropathy, obstructive or restrictive lung diseases, serum creatinine > 1.5 mg%, received steroid supplementation and who were having repeat spine surgeries were excluded from the study. Preanesthetic evaluation was done on the previous day of surgery. All patients were fasted overnight and premedicated with Tab. Pantaprazole 40 mg and Tab. Alprazolam 0.5 mg on the night before surgery. Randomization was done using computer generated table and opaque sealed envelope was used for allocation (Figure 1). Patients were categorized to Group V – (patients who received volume controlled ventilation or Group P –(patients who received pressure controlled ventilation). The required sample size was derived based on a pilot study that estimated mean difference in peak airway pressure (P peak) of 5 cm H_2O in the two desired Groups (mean ± standard deviation in Group V was 21.4 ± 4.16 cm H_2O and Group P was 19.2 ± 2.41 cm H_2O). With 80% power and 5% level of significance, the sample size was estimated to be 36 patients in each group, (Table 1).

In the operation theatre, patients were connected to standard monitors (electrocardiography,

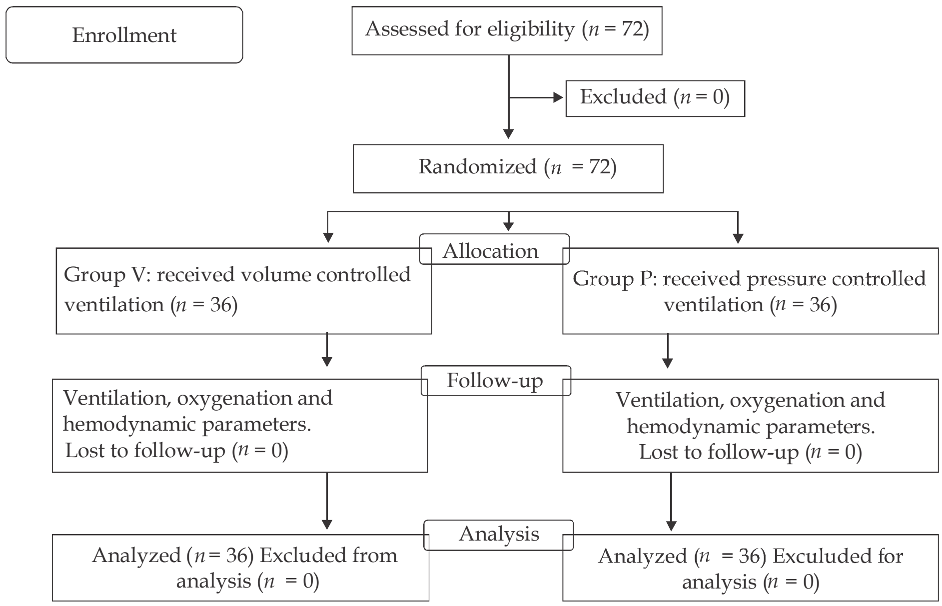

Fig. 1: Consort diagram

Table 1: Descriptive statistics

Variables	Group P (*n* = 36)	Group V (*n* = 36)	*p* - value
Age (years)	47.6 ± 12.4	45.6 ± 10.7	0.52
Sex, *n* (%)			
Male	16 (44.4)	13 (36.1)	0.47
Female	20 (55.6)	23 (63.9)	
BMI (kg/m^2)	24.5 ± 3.8	24.4 ± 4.2	0.97
Duration of surgery (minutes)	193.14 ± 64.47	195.42 ± 64.82	0.88

BMI- Body mass index

noninvasive blood pressure, capnography and pulse oximetry) and an intravenous (IV) access was secured. After optimal preoxygenation, they were premedicated with IV midazolam 1 mg, glycopyrrolate 0.2 mg and fentanyl 2 µg/kg. Induction was done with propofol 2 mg/kg or till the loss of verbal contact and atracurium 0.6 mg/kg. Appropriate sized endotracheal tube was placed, position confirmed and secured. Patients were then ventilated with oxygen - nitrous oxide - isoflurane mixture and received either VCV or PCV. An Arterial Blood Gas (ABG) was done and the same was considered as baseline for comparison with ABG on prone position.

We used longitudinal bolsters which partially compressed the chest, abdomen was kept free, pelvis was partially supported and legs were positioned at heart level. Eyes and peripheral pressure areas were adequately padded. All patients were ventilated with Anesthesia workstation (Datex Ohmeda Aestiva/5®; GE Healthcare, Finland), tidal volume (Vt) in VCV and P peak in PCV were adjusted to deliver Vt of 8 ml/kg ideal body weight and Respiratory Rate [RR] in both Groups were adjusted to keep end tidal carbon oxide ($EtCO_2$) between 33–36 mm Hg. Both the Groups had standardized ventilatory settings with Fractional inspired oxygen concentration (FiO_2) of 0.4, Positive End Expiratory Pressure (PEEP) of 5 cm H_2O and Inspiratory: Expiratory time (I:E) of 1:2 ratio. Anesthesia was maintained with Nitrous oxide - oxygen, Isoflurane, atracurium and morphine. Inhalational agents and fluids were titrated to keep mean arterial pressure within 20% of baseline. Hourly urine output and estimated blood loss during surgery were noted. Normothermia was maintained throughout surgery. Ventilation, oxygenation and circulation variables were measured every 10 min for first half hour and then every 30 min until end of surgery. At the end of surgery, ABG was taken and the patient repositioned to supine position. Adequate reversal was done with IV neostigmine 50 mcg/kg and glycopyrrolate 10 mcg/kg and the patient was extubated. The patient was monitored in the recovery room and shifted to the ward once stable.

The following variables were recorded during the study:

(a). Ventilation and Oxygenation parameters –

Peak airway pressure (P peak), mean airway pressure (P mean), PEEP, $EtCO_2$, exhaled tidal volume (Vte), RR, Minute Ventilation (MV), dynamic compliance of the respiratory system (C_{dyn}). The partial pressure of arterial oxygen (PaO_2), the ratio of PaO_2 to fractional inspired oxygen concentration (PaO_2/FiO_2) and ratio of alveolar dead space to tidal volume ratio (V_D/V_T) were derived from the ABG.

(b). Hemodynamic data – Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), Heart Rate (HR) were recorded.

Data was tabulated in excel sheet and the parameters were statistically analyzed at 5 min after intubation (S_5) in supine position (baseline) and at one hour (P_{60}) in prone position and at three hours (P_{180}) of prone position. Statistical analysis was done using SPSS version 18 (SPSS Inc, Chicago, Illinois, USA). Descriptive statistics were summarized for continuous (mean and standard deviation) and categorical (counts with percentages) variables. Chisquare test was used to test the association between the categorical variables. Data between groups were compared using an independent t-test. Respiratory and hemodynamic changes after prone position within the group were compared using paired t-test. Repeated measures ANOVA were used to compare the hemodynamic parameters between the two Groups over time. $p < 0.05$ was considered statistically significant.

Results

The demograhics (Age, Sex, BMI) and duration of surgery were comparable in both the groups. P peak and P mean increased from supine to prone position in both the groups. The P peak in VCV was higher than PCV in prone position and the difference was significant at first hour (p = 0.008) and stabilised by end of surgery (p = 0.29). The Cdyn decreased in both PCV and VCV from supine to prone position. In prone position, there was significant increase in Cdyn in PCV at the end of first hour (p = 0.005) and stabilized thereafter, (p = 0.59). However, Vte, MV, PEEP, RR, $EtCO_2$, and V_D/V_T did not show any significant difference between the groups ($p > 0.05$). The oxygenation parameters (PaO_2, PaO_2/FiO_2) and hemodynamics (HR, SBP, DBP and MAP) were also comparable in both the Groups. There was no significant difference in estimated blood loss between the Groups.

Discussion

Optimization by various modes of ventilation such as VCV, PCV and pressure controlled ventilation with volume guarantee (PCV-VG) has been a topic of debate. Hemodynamics, gas exchange, mechanical properties of lung and chest wall are considered to guide the mechanical ventilation strategies.[9] Traditionally, VCV has been used in the OT for all types of surgeries. The recent availability of anesthesia ventilators with pressure control modes has made effective ventilation possible even in noncompliant lungs such as chronic obstructive lung diseases (COPD) patients, thoracic surgery or intensive care unit (ICU) patients with respiratory diseases.

VCV uses a constant flow to deliver Vt resulting in high airway pressure, decreased compliance in chest wall and lung, reduced functional residual capacity impairing alveolar ventilation as in laparoscopic surgeries and leading to acute lung injury.[5,10] It does not compensate for leaks and varies with changes in airway resistance, lung compliance and integrity of the ventilator circuit. In comparison, PCV maintains the pressure gradient in proximal airway and alveoli with initial high speed flow which allows recruitment of even the unstable alveoli. The deceleration following this keeps inspiratory pressure constant and allows redistribution of Vt in alveoli with different time constants.[11] PCV provides a lower P peak and higher P mean. It reduces intrathoracic pressure and pulmonary vascular resistance and improves right ventricular function.[12] Thus, PCV has advantage of improving ventilation perfusion ratio and oxygenation. However, it does not guarantee minute ventilation, and therefore, requires more monitoring by the operator. P peak reflects the dynamic compliance of the respiratory system whereas, the plateau pressure reflects the static compliance. P mean is the average pressure of the respiratory system throughout inspiration and determines recruitment of collapsed alveoli and redistribution of blood flow and adds as a critical factor for gas exchange.

In anesthetized patients, mechanical ventilation maintains adequate gas exchange through out the intraoperative period. Prone position during general anesthesia interferes with respiratory mechanics and improves oxygenation.[13] The results in our study, showed that when compared to supine, P peak was increased by 4.6% in prone position at first hour and by 3% in third hour in VCV Group and was comparable at both time points in PCV Group. However, the increase in P peak was lesser in PCV compared to VCV and showed statistical significance at first hour p = 0.008. When compared to supine position, Cdyn decreased by13.9% in first hour and 10.4% in third hour of prone position in VCV Group. The decrease was 10% in first hour and by 13% in third hour of prone position in PCV Group. The decrease was more in VCV compared to PCV and showed statistical significance at first hour between the two groups (p = 0.005). Between the groups, none of them showed any clinical significance in oxygenation, elimination of carbon dioxide and the physiological dead space ($p >$ 0.05). At 30 min after prone position, Jo et al. found decrease of Cdyn by 17% in VCV and 23% in PCV and a similar (< 2%) increase in P peak and P mean in both the groups.[1] Palmon et al. found increase in P peak and decrease in Cdyn and attributed the change in pulmonary mechanics to the frame used for positioning rather than body habitus. Greater compromise in ventilatory function was seen more on Wilson frame and chest rolls rather than Jackson table.[14] Results were similar in one lung ventilation in prone position for robot assisted esophagectomy[8], anterior cervical discectomy and fusion surgery in supine position[15] and laparoscopy cholecystectomy in reverse trendenlenberg position.[16] Tan et al. found PCV beneficial for one lung ventilation during radical resection of pulmonary carcinoma by video assisted thoracoscopic procedure. It reduced P peak and levels of proinflammatory markers thereby reducing airway injury.[17] Significant advantage of Cdyn with PCV was noted in different positions. In steep trendelenburg position for robot assisted laparoscopic radical prostatectomy, the Cdyn (mean ± SD) in PCV was 18.6 ± 3.6 ml/cm H_2O and in VCV was 15.5 ± 1.8 ml/cm H_2O.[7] The surgeries with prone position as in robot assisted radical esophagectomy during one lung ventilation, the Cdyn was 24.3 ± 6.6 ml/cm H_2O in PCV and 22.9 ± 4.3 ml/cm H_2O in VCV and in lumbar spine surgeries 44 ± 8.2 ml/cm H_2O in PCV and 39.1 ± 6.8 ml/cm H_2O in VCV.[1,8] However, pooled analysis of seven studies in meta-analysis showed no significant difference in dynamic compliance (WMD, 2.81 ml/cm H_2O, 95% CI – 1.68–3.95; p < 0.05) between the two groups.[18]

The p peak (mean ± SD) was 29 ± 5.8 cm H_2O in PCV and 35.7 ± 4.7 cm H_2O in VCV in steep Trendelenburg position and 26.5 ± 6.06 cm H_2O in PCV and 29.5 ± 5.9 in VCV in prone position in the robot assisted surgeries.[7,8] In prone position of spine surgeries, it was 14.4 ± 2.3 cm H_2O in PCV and 16.9 ± 2.5 cm H_2O in VCV.[1] These studies favored PCV over VCV. PCV reduced the p peak and Plateau airway pressure (WMD, -1.16 cm H_2O, 95% CI -2.11 to -0.20; p = 0.02). The pooled analysis of 25 studies in the meta-analysis also showed a significant difference between the groups (WMD, -4.34 cm H_2O, 95% CI -5.25 to -3.42; p < 0.05).[18]

Meta-analysis showed PCV is more efficient in eliminating carbon dioxide as it facilitates the recruitment of unstable alveoli and allows equitable distribution of Vt thereby, recruiting more alveoli in gas exchange. The high Vt to maintain acceptable $PaCO_2$ in VCV on the other hand may overdistend the lung region not involved in gas exchange. The newer mode PCV-VG used in the recent times has the benefits of both PCV and VCV. It's a variant of PCV (decelerating flow with constant pressure) which changes to constant flow ventilation (VCV) when the targeted Vt is not achieved in PCV.[15] The compliance of the lung is calculated and the lowest possible pressure to deliver set targeted Vt is achieved.[16]

Provhilo trial did not show any benefit with low and high PEEP in lower abdominal surgeries.[19] In our study, we had standardized PEEP to 5 cm H_2O in all patients and did not find any difference at any time points in both the groups. The driving pressure (Δ P) of the respiratory system is defined as the difference of plateau pressure of airway at end inspiration and PEEP (Δ P = P plat – PEEP). In a retrospective data on 109, 360 adults, postoperative pulmonary complications (reintubation, pulmonary edema, pulmonary failure and pneumonia) was associated more with PCV compared to VCV due to more varied driving pressures and tidal volumes exacerbated by low or no PEEP (Odds ratio with driving pressure ≤ 19 cm H_2O was 1.37, p < 0.001 and in Δ P ≥ 19 cm H_2O was 1.16 , p = 0.011 with a relative risk of 1.18, p = 0.016)[20] Since, Δ P indicates severity of lung disease and is associated with complications and mortality, Pelosi et al. recommended to use Δ P to individually optimize mechanical ventilation.[9]

Oxygenation parameters

Oxygenation depends on inspired oxygen concentration, alveolar ventilation and intrapulmonary shunts which were all well maintained in the prone position in our study.

P mean determines the distribution of ventilation and recruitment of collapsed alveoli and is important factor for gas exchange.[21] There was statistical significance observed in the P mean (p < 0.05) between the two groups at one hour after prone position. The PEEP remained insignificant at all time points. However, there was no beneficial clinical effect on oxygenation between the groups observed in our study (PaO_2/FiO_2 and PaO_2 showed no significance). Though, no extrinsic PEEP was added to their subjects on lumbar spine surgeries in prone position, Jo YY et al. did not observe any significance.[1] In anterior spine surgeries, the PaO_2/FiO_2 (p = 0.8) and oxygenation index (p = 0.6) were comparable in both groups.[15] The oxygenation was well-maintained in patients in laparoscopic cholecystectomy (head up position) irrespective of VCV, PCV, PCV-VG mode of ventilation.[16] In contrast, PCV showed better oxygenation than VCV in obese patients with bariatric surgeries.[22,23] This maybe attributed to the higher ventilation perfusion mismatch in obese patients with pneumoperitoneum. PCV mode did not show any superiority over VCV to improve oxygenation in radical resection of pulmonary carcinoma by video assisted thoracoscopic surgery, indicating that body position, anesthetic drugs (hypoxic pulmonary vascular constriction) and anesthetic methods used are also responsible to the events of intraoperative or postoperative hypoxemia.[17] Though meta-analysis on twenty two studies showed significant difference in P mean in both the groups, the sub-group analysis on different positions such as steep trendelenberg and prone position did not show any significant difference.[18]

Hemodynamic parameters

Along with mechanical ventilation strategies, currently other preoperative and intraoperative techniques are also used to reduce blood loss and transfusion requirements such as cell saver, recombinant factor VIIa, and perioperative antifibrinolytic agents (such as aprotinin, tranexamic acid, epsilon-aminocaproic acid).[24] Hemodynamic changes occur from supine to prone position which is attributed to raised intraabdominal pressure (IAP) causing decreased venous return and ventricular compliance. Raised IAP causes epidural venous system congestion, increases blood loss and prolongs surgical time during spine surgery.[4,25] Also, the high venous pressure may result in decreased spinal cord perfusion pressure (MAP - Spinal venous pressure) and increases the risk of neurological complications.[14]

The increase in P peak, and P plateau maybe noticed in improper position and obese individuals. Koh et al. concluded such increase may predict and correlate to intraoperative surgical blood loss (p peak $R^2 = 0.405$ and P plat R^2 is 0.489).[4] Increase in Peak inspiratory pressure is attributed not only to decrease in lung and chest compliance, but also increase in airway resistance caused by drainage of secretive fluids due to gravity from change in body position, location and kink of endotracheal tube.[2] Respiratory dynamics using P peak, and Cdyn were evaluated between the two modes of ventilation in our study. There was a decrease in P peak and increase in Cdyn in PCV compared to VCV at the end of 1 hour which was statistically significant between the groups, (Table 2).

Table 2: Ventilatory parameters

Variables	Time (minutes)	Group P	Group V	*p* - value
P peak	S5	17.8 ± 3.2	17.5 ± 3.5	0.75
(cm H_2O)	P60	19.2 ± 2.4	21.4 ± 4.2	0.008**
	P180	19.5 ± 2.4	20.5 ± 3.6	0.29
P mean	S5	9.6 ± 3.2	8.4 ± 2.4	0.08
(cm H_2O)	P60	10.4 ± 2.4	9.2 ± 2.8	0.05*
	P180	9.9 ± 2.4	9.0 ± 2.6	0.22
PEEP	S5	4.43 ± 0.91	4.03 ± 1.05	0.09
(cm H_2O)	P60	4.43 ± 0.94	3.97 ± 1.05	0.06
	P180	4.45 ± 0.96	3.92 ± 1.08	0.22
C dyn	S5	40.4 ± 11.1	37.8 ± 11.1	0.33
(ml/cm H_2O)	P60	33.9 ± 7.5	29.3 ± 5.8	0.005**
	P180	31.7 ± 6.7	30.4 ± 8.1	0.59
Vte (ml)	S5	510.9 ± 78.5	499.0 ± 58.3	0.47
	P60	482.9 ± 108.7	503.8 ± 59.6	0.32
	P180	484 ± 58.0	458.4 ± 115	0.36
MV (L/min)	S5	6.18 ± 1.08	6.13 ± 1.16	0.19
	P60	6.09 ± 1.25	5.88 ± 1.10	0.76
	P180	5.94 ± 1.11	5.83 ± 1.25	0.31
RR (rpm)	S5	12.5 ± 1.3	12.6 ± 1.2	0.63
	P60	12.4 ± 1.16	12.0 ± 1.9	0.34
	P180	12.3 ± 1.4	12.2 ± 1.8	0.96
$EtCO_2$ (mm Hg)	S5	32.7 ± 3.6	32.8 ± 5.0	0.98
	P60	30.7 ± 3.6	29.9 ± 3.1	0.32
	P180	31.0 ± 3.8	31.4 ± 3.6	0.47

*Peak airway pressure (P peak), *Mean airway pressure (P mean), Positive End Expiratory P (PEEP), *Dynamic Compliance of the Respiratory system (C_{dyn}), Exhaled Tidal Volume (V_{te}), Minute Ventilation (MV), Respiratory Rate (RR), End Tidal Carbon Oxide ($EtCO_2$). S5 - 5 minutes in Supine Position, P60 - 60 minutes in Prone, P180 – 180 minutes in Prone Position.

Table 3: Hemodynamic parameters

Variables	Time	Group P	Group V	*p* - value
HR (bpm)	S5	86.0 ± 17.4	91.2 ± 17.7	0.21
	P60	73.6 ± 17.5	78.1 ± 11.7	0.21
	P180	69.3 ± 14.2	75.3 ± 14.6	0.17
SBP (mm Hg)	S5	110.3 ± 17.0	111.1 ± 20.6	0.86
	P60	101.6 ± 15.6	98.8 ± 10.2	0.37
	P180	106.8 ± 18.2	102.4 ± 17.5	0.42

Variables	Time	Group P	Group V	p - value
DBP (mm Hg)	S5	70.37 ± 11.98	68.81 ± 10.34	0.55
	P60	66.5 ± 14.9	68.3 ± 7.5	0.52
	P180	69.1 ± 8.7	68.4 ± 8.5	0.77
MAP (mm Hg)	S5	80.9 ± 15.0	84.6 ± 14.5	0.30
	P60	79.6 ± 12.5	78.9 ± 7.8	0.77
	P180	79.2 ± 8.6	76.8 ± 7.6	0.34

Heart Rate (HR), Systolic BloodP (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP)

Table 4: ABG derived parameters

Variables	Position	Group P	Group V	p - value
PaO_2 (mm Hg)	Supine	217.26 ± 83.69	244.08 ± 119.72	0.27
	Prone	235.51 ± 99.99	211.05 ± 94.81	0.29
$PaCO_2$ (mm Hg)	Supine	38.31 ± 7.12	38.03 ± 5.96	0.85
	Prone	35.88 ± 5.17	37.66 ± 4.89	0.13
PaO_2/FiO_2	Supine	426.15 ±182.12	428.87 ± 132.51	0.94
	Prone	454.46 ± 212.46	406.9 ± 157.79	0.29
V_D / V_T	Supine	0.136 ± 0.09	0.149 ± 0.11	0.60
	Prone	0.198 ± 0.14	0.163 ± 0.11	0.26
Hb gm%	Supine	12.31 ± 1.86	12.45 ± 2.19	0.78
	Prone	11.06 ± 1.82	11.05 ± 1.68	0.98

Comparison of parameters in Supine at 5 min (baseline) and end of surgery in prone position. Partial pressure of arterial oxygen (PaO_2), partial pressure of arterial carbon dioxide ($PaCO_2$), ratio of partial pressure of arterial oxygen to fractional inspired oxygen concentration (PaO_2/FiO_2) and ratio of alveolar dead space to tidal volume ratio (V_D/V_T).

In our healthy patients, there was no clinical and statistical difference in hemodynamic parameters, (Table 3), estimated blood loss (mean ± SD, Group P - 457.35 ± 206.75 ml, Group V 504.29 ± 191.5 ml; p = 0.33), or Hemoglobin in both the groups. The alterations may produce a significant hemodynamic effect in patients with limited cardiac reserve[26] (Table 4).

The transthoracic echocardiography (TTE) findings in positioning prone with longitudinal bolsters showed that the inferior vena cava compression decreased the venous return and increased intrathoracic pressure and decreased the left ventricular compliance.[27] Sreenivasa et al. in their Transesophageal Echocardiography (TEE) study comparing five different positioning systems (Siemens frame, Andrews frame, Wilson frame, Jackson frame and the bolster system) found the Jackson frame and bolsters had the least effect on cardiac performance. Cardiac output decreased with Wilson, preload decreased with Andrews, cardiac index and stroke volume decreased in Siemens,Wilson and Andrew frames. They also found that adequate fluid resuscitation after a presurgical fast reduced changes in blood pressure and heart rate after prone position.[26] Based on this, all patients were also given 500 ml crystalloid before they were turned prone in our study. Inspite of longitudinal bolsters which had partial pressure on the chest, the hemodynamic changes did not show any significance between the two modes of ventilation in this study.

Cardiac, hemodynamic and respiratory variables are thus used to predict intraoperative surgical blood loss. Proper positioning with no/minimal compression on abdomen and chest is mandatory. Vigilant monitoring of adequate tidal volume, respiratory rate, peak airway pressure and lung compliance is therefore, required by the clinician irrespective of the ventilator mode (volume *vs* pressure controlled ventilation). The limitations in our study was that ours was a single centre study done on patients with normal lungs. We did not follow up for postoperative pulmonary complications or oxygenation index either. The same results cannot be extrapolated to diseased lung patients. More randomized studies involving not only indices but also postoperative clinical outcomes are needed to make conclusions on which mode is superior. Currently, lung protective strategies using low Vt, longer inspiration time, appropriate PEEP and recruitment manoeuvres are conducive to improve respiratory mechanics in surgical patients.

Though beneficial effect of P peak, P mean and dynamic compliance was noted in PCV group in our study, there was no significant clinical difference of respiratory, oxygenation and hemodynamic parameters between PCV and VCV. In conclusion, both the modes can be safely used to ventilate patients in prone position undergoing lumbar spine surgeries.

References

1. Jo YY, Kim JY, Kwak YL, et al. The effect of pressure-controlled ventilation on pulmonary mechanics in the prone position during posterior lumbar spine surgery: A comparison with volume-controlled ventilation. J Neurosurg Anesthesiol 2012 Jan;24(1):14–18.
2. Nam Y, Yoon AM, Kim YH, et al. The effect on respiratory mechanics when using a Jackson surgical table in the prone position during spinal surgery. Korean J Anesthesiol 2010 Nov;59(5):323–28.
3. Tusman G, Böhm SH, Warner DO, et al. Atelectasis and perioperative pulmonary complications in high-risk patients. Curr Opin Anesthesiol 2012 Feb;25(1):1–10.
4. Jae Chul Koh, Jong Seok Lee, Dong Woo Han, et al. Increase in airway pressure resulting from prone position patient placing may predict intraoperative surgical blood loss. Spine 2013 May 15;38(11):E678–82.
5. Eichen berger A, Proietti S, Wicky S, et al. Morbid obesity and postoperative pulmonary atelectasis: An underestimated problem. Anesth Analg 2002 Dec;95(6):1788–792.
6. Manna EM, Ibraheim OA, Samarkandi AH, et al. The effect of prone position on respiratory mechanics during spinal surgery. Middle East J Anesthesiol 2005 Oct;18(3):623–30.
7. Choi EM, Na S, Choi SH, et al. Comparison of volume-controlled and pressure-controlled ventilation in steep Trendelenburg position for robot-assisted laparoscopic radical prostatectomy. J Clin Anesth 2011 May;23(3):183–88.
8. Choi YS, Shim JK, Na S, et al. Pressure-controlled versus volume-controlled ventilation during one-lung ventilation in the prone position for robot-assisted esophagectomy. Surg Endosc 2009 Oct;23(10):2286–291.
9. Paolo Pelosi and Lorenzo Ball. Should we titrate ventilation based on driving pressure? Maybe not in the way we would expect. Ann Transl Med 2018 Oct;6(19): 389.
10. Davis K Jr, Branson RD, Campbell RS, et al. Comparison of volume control and pressure control ventilation: Is flow waveform the difference? J Trauma 1996 Nov;41(5):808–814.
11. Campbell RS and Davis BR. Pressure-controlled versus volume-controlled ventilation: Does it matter? Respir Care 2002 Apr;47(4):416–24.
12. Al Shehri AM, El-Tahan MR, Al Metwally R, et al. Right ventricular function during one-lung ventilation: Effects of pressure-controlled and volume-controlled ventilation. J Cardiothorac Vasc Anesth 2014 Aug;28(4):880–84
13. Pelosi P, Croci M, Calappi E, et al. The prone positioning during general anesthesia minimally affects respiratory mechanics while improving functional residual capacity and increasing oxygen tension. Anesth Analg 1995 May;80(5):955–60.
14. Palmon SC, Kirsch JR, Depper JA, et al. The effect of the prone position on pulmonary mechanics is frame-dependent. Anesth Analg 1998 Nov;87(5):1175–180.
15. Moningi S, Elmati PK, Rao P, et al. Comparison of volume control and pressure control ventilation in patients undergoing single level anterior cervical discectomy and fusion surgery. Indian J Anesth 2017 Oct;61(10):818–25.
16. Kothari A, Baskaran D. Pressure-controlled volume guaranteed mode improves respiratory dynamics during laparoscopic cholecystectomy: A Comparison with conventional modes. Anesth Essays Res 2018 Jan–Mar;12(1):206–212.
17. Tan J, Song Z, Bian Q, et al. Effects of volume-controlled ventilation vs pressure-controlled ventilation on respiratory function and inflammatory factors in patients undergoing video-assisted thoracoscopic radical resection of pulmonary carcinoma. J Thorac Dis 2018 Mar;10(3):1483–489.
18. Jiang J, Li B, Kang N, et al. Pressure-controlled versus volume-controlled ventilation for surgical patients: A Systematic review and meta-analysis J Cardiothorac Vasc Anesth 2016 Apr;30(2):501–514.
19. Hemmes SN, Gama de Abreu M, Pelosi P, et al. High versus low positive end-expiratory pressure during general anesthesia for open abdominal surgery (Provhilo trial): A multicentre randomized controlled trial. Lancet 2014 Aug 9;384(9942):495–503.
20. Bagchi A, Rudolph MI, Ng PY, et al. The association of postoperative pulmonary complications in 109,360 patients with pressure-controlled or volume-controlled ventilation. Anesthesia 2017 Nov;72(11):1334–343.
21. Movassagi R, Montazer M, Mahmoodpoor A, et al. Comparison of pressure vs volume controlled ventilation on oxygenation parameters of obese patients undergoing laparoscopic cholecystectomy. Pak J Med Sci

2017 Sep–Oct;33(5):1117–122.

22. Cadi P, Guenoun T, Journois D, et al. Pressure-controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled ventilation. Br J Anesth 2008 May;100(5):709–716.

23. Gupta SD, Kundu SB, Ghose T, et al. A comparison between volume-controlled ventilation and pressure-controlled ventilation in providing better oxygenation in obese patients undergoing laparoscopic cholecystectomy. Indian J Anesth 2012;(56):276–82.

24. Elgafy H, Bransford RJ, McGuire RA, et al. Blood loss in major spine surgery: Are there effective measures to decrease massive hemorrhage in major spine fusion surgery? Spine 2010 Apr 20;35(9 Suppl):S47–56.

25. Park CK. The effect of patient positioning on intraabdominal pressure and blood loss in spinal surgery. Anesth Analg 2000 Sep;91(3):552–57.

26. Dharmavaram S, Jellish WS, Nockels RP, et al. Effect of prone positioning systems on hemodynamic and cardiac function during lumbar spine surgery: An Echocardiographic Study. Spine 2006;31(12):1388–393.

27. Toyota S, Amaki Y. Hemodynamic evaluation of prone position by transesophageal echocardiography. J Clin Anesth 1998 Feb;10(1):32–35.