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

Srilata Moningi, Praveen Kumar Elmati, Prasad Rao, Geetha Kanithi, Dilip Kumar Kulkarni, Gopinath Ramachandran
Department of Anaesthesia and Intensive Care, Nizam’s Institute of Medical Sciences, Hyderabad, Telangana, India

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 PaO$_2$/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 PaO$_2$/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
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 (V₉) of 8 mL/kg and positive end expiratory pressure (PEEP) of 5 cm H₂O. The initial V₉ 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 V₉ 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 V₉ 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 V₉ of 8 mL/kg, RR was adjusted to keep an EtCO₂ of 35–40 mmHg.
Following an increase in \( \text{EtCO}_2 \), the RR was increased by 2/min every 5 min till 20/min, achieving the target \( \text{EtCO}_2 \). Following a fall in \( \text{EtCO}_2 <35 \) mmHg, the RR was decreased by 2/min every 5 min till 8/min, with a decrease in PIP by 2 cmH\(_2\)O every 5 min until 30 cmH\(_2\)O. Patients in PCV requiring PIP >30 cmH\(_2\)O 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 (\( P_{\text{mean}} \)), \( P_{\text{plat}} \), and ABG findings (\( \text{PaO}_2/\text{FiO}_2 \), \( \text{PaO}_2 \), \( \text{P(a-A)} _2 \), and \( \text{PaCO}_2 \)). The P(a-ET) \( \text{CO}_2 \) was calculated as the difference between arterial and \( \text{EtCO}_2 \) partial pressures obtained simultaneously. Blood pressure (BP) was continuously measured from the radial artery catheter. Other variables measured were \( \text{EtCO}_2 \), mean arterial pressure, HR, \( \text{SpO}_2 \), \( V_T \), RR and inspiration:expiration (I:E) ratio. Static compliance (\( C_{\text{stat}} \)), dynamic compliance (\( C_{\text{dyn}} \)), oxygenation index and dead space ventilation (\( V_g/V_t \)) are derived parameters. \( C_{\text{stat}} \) is derived from the formula: \( V_T/P_{\text{plat}} - \text{PEEP} \) and \( C_{\text{dyn}} \) from \( V_T/P_{\text{mean}} - \text{PEEP} \). Oxygenation index is measured from the formula: \( \text{FiO}_2/\text{PaO}_2 \times P_{\text{mean}} \) and \( V_T/V_g \) is calculated from the formula: \( \text{P(a-ET)} \times \text{PaCO}_2/\text{PaO}_2 \). \( \text{PaO}_2 \) was derived from the equation: \( \text{FiO}_2(P_{\text{aT}} - \text{pH}_2O) - \text{PaCO}_2/\text{RER} \) where \( \text{RER} \) 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 \( \geq 2 \) 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, \( \text{PaO}_2/\text{FiO}_2 \) 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.

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 ± 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
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\textsubscript{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\textsubscript{stat} and C\textsubscript{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. Patients who have cervical spine problems can have associated quadripareisis and respiratory muscle weakness, which may further compromise respiratory dynamics. VCV is routinely used in the intraoperative period. PCV has the advantage of limiting the airway pressures and thus increases the C\textsubscript{dynam} and improves the oxygenation. 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.

Literature has shown similar comparative evaluation in patients undergoing laparoscopic cholecystectomy but none with regards to cervical spine surgery. 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. The time taken for surgery is proportional to the number of levels involved. Prolonged retraction and increased blood loss may further compromise respiratory dynamics.

---

**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/m²)            | 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 PaO₂ (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.
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 H₂O)           | 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                    |             |             |         |                         |             |             |         |
|                        |            |                         |             |             |         |                         |             |             |         |
| Psys (cm H₂O)          | 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 Pmean (cm H₂O) | 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         |         |
| PaCO₂ (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) CO₂ (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*       |         |
| PaO₂ (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        | 0.99    | 232.5                   | −25.1       | 19.2        | 0.8     |
| PaO₂/FiO₂              | 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        | 0.99    | 465                    | −50.1       | −38.4       | 0.8     |
| PAO₂ (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 O₂               | 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)O₂ (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        | 0.99    | 79.5                    | −16.1       | 26.6        | 0.6     |
| Cdil (mL/cm H₂O)       | 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         |         |                         |             |             |         |
| Cdyn (mL/cm H₂O)       | T1         | 37                      |             |             |         |                         |             |             |         |
|                        | 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 (Vd/Vi) | T1 | 0.09                    |             |             |         |                         |             |             |         |
|                        | 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                     |             |             |         |                         |             |             |         |
|                        | T2         | 1.7                     | −0.3        | 0.06        | 0.36    | 1.6                     | −0.3        | 0.08        | 0.6     |

Contd...
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 $VT$. Significant improvement in oxygenation ($PaO_2$ and $PaO_2/FiO_2$) and V/Q ratio was reported with PCV compared to VCV in morbidly 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/$VT$ 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 $VT$ 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 2: Contd...**

| Respiratory parameters | Time points | Group VCV (mean) | Lower 95% CI | Upper 95% CI | $P$ | Group PCV (mean) | 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; $PaCO_2$ – Partial pressure of arterial carbon dioxide; P(a-ET) $CO_2$ – Difference of partial pressure of arterial and end tidal carbon dioxide; $VD$ – Dead space volume; $VT$ – Tidal volume; $PaO_2$ – Partial pressure of arterial oxygen content; $PAO_2$ – Partial pressure of alveolar oxygen content; $FiO_2$ – 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
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. A recent study on thoracic surgery has shown beneficial effects of PCV-VG compared to VCV in patients with OLV. 

In contrast, comparable results were seen with VCV, PCV and PCV-VG in patients undergoing abdominal surgery.

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.

**Financial support and sponsorship**
Nil.

| Parameters                  | 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         |              |     | T0 90.4                 | 95.3         |              |     |
|                            | 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                 |              |              |     | T0 90                   |              |              |     |
|                            | 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                  |              |              |     | T1 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                  |              |              |     | T1 1.2                  |              |              |     |
|                            | 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                 |              |              |     | T1 22.4                 |              |              |     |
|                            | 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 retractor; T3 – 20 min after removal of the retractor; MAP – Mean arterial pressure; HR – Heart rate; pH – Negative algorithm of hydrogen ion concentration; HCO$_3^-$ – Bicarbonate; SD – Standard deviation; $P$ – Probability. $P < 0.005$; this is the overall significance between the two groups.
Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Garnero AJ, Abbona H, Gordo-Vidal F, Hermosa-Gelbard C; Grupo de Insuficiencia Respiratoria Aguda de SEMICYUC. Pressure versus volume controlled modes in invasive mechanical ventilation. Intensiva 2013;37:292-8.

2. Prella M, Feihl F, Domenighetti G. Effects of short-term pressure-controlled ventilation on gas exchange, airway pressures, and gas distribution in patients with acute lung injury/ARDS: Comparison with volume-controlled ventilation. Chest 2002;122:1382-8.

3. Nichols D, Haranath S. Pressure control ventilation. Crit Care Clin 2007;23:183-99, viii ix.

4. Sagi HC, Beutler W, Carroll E, Connolly PJ. Airway complications associated with surgery on the anterior cervical spine. Spine (Phil Pa 1976) 2002;27:949-53.

5. Grimm DR, Chandy D, Almenoff PL, Schilero G, Lesser M. Airway hyperreactivity in subjects with tetraplegia is associated with reduced baseline airway caliber. Chest 2000;118:1397-404.

6. Baydur A, Adkins RH, Milic-Emili J. Lung mechanics in individuals with spinal cord injury: Effects of injury level and posture. J Appl Physiol 2001;90:405-11.

7. Gupta SD, Kundu SB, Ghose T, Maiti K, Mukherjee M, et al. A comparison between volume-controlled ventilation and pressure-controlled ventilation in providing better oxygenation in obese patients undergoing laparoscopic cholecystectomy. Indian J Anaesth 2012;56:276-82.

8. Cadi P, Guenoun T, Journois D, Chevallier JM, Diehl JL, Safran D. Pressure-controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled ventilation. Br J Anaesth 2008;100:709-16.

9. Terao Y, Matsumoto S, Yamashita K, Takada M, Inadomi C, Fukusaki M, et al. Increased incidence of emergency airway management after combined anterior-posterior cervical spine surgery. J Neurosurg Anesthesiol 2004;16:282-6.

10. Unzueta MC, Casas JI, Moral MV. Pressure-controlled versus volume-controlled ventilation during one-lung ventilation for thoracic surgery. Anesth Analg 2007;104:1029-33.

11. Tugrul M, Camci E, Karadeniz H, Sentürk M, Pembeči K, Akpir K. Comparison of volume controlled with pressure controlled ventilation during one-lung anaesthesia. Br J Anaesth 1997;79:306-10.

12. Li J, Xu XH, Zou XH, Chang YT. Pressure-controlled versus volume-controlled ventilation during one-lung ventilation for thoracic surgery. J Pract Med 2009;11:1771-3.

13. Li FR, Ding J, Gao J, Geng EJ, Shen LN. Comparison of pressure controlled with volume controlled ventilation in lung protective strategy during aged patient’s one-lung anesthesia. Shandong Med J 2009;49:11-3.

14. Al Shehri AM, El-Tahan MR, Al Metwally R, Qutub H, El Ghoneemy YF, Regal MA, et al. Right ventricular function during one-lung ventilation: Effects of pressure-controlled and volume-controlled ventilation. J Cardiothorac Vasc Anesth 2014;28:880-4.

15. Kim KN, Kim DW, Jeong MA, Sin YH, Lee SK. Comparison of pressure-controlled ventilation with volume-controlled ventilation during one-lung ventilation: A systematic review and meta-analysis. BMC Anesthesiol 2016;16:72.

16. Rieu Y, Chaari W, Létetre S, Leclerc F. Predictive value of the physiological deadspace/tidal volume ratio in the weaning process of mechanical ventilation in children. J Pediatr (Rio J) 2012;88:217-21.

17. Campbell RS, Davis BR. Pressure-controlled versus volume-controlled ventilation: Does it matter? Respir Care 2002;47:416-24.

18. David M, Bodenstein M, Markstaller K. Protective ventilation therapy. Also relevant for the operating room? Anaesthesist 2010;59:595-606.

19. Boules NS, Ghobrial HZ. Efficiency of the newly introduced ventilatory mode “pressure controlled ventilation-volume guaranteed” in thoracic surgery with one lung ventilation. Egypt J Anaesth 2011;27:113-9.

20. Pu J, Liu Z, Yang L, Wang Y, Jiang J. Applications of pressure control ventilation volume guaranteed during one-lung ventilation in thoracic surgery. Int J Clin Exp Med 2014;7:1094-8.

21. Boules N, El Ramely M. Does pressure-controlled ventilation-volume guaranteed differ from pressure-controlled ventilation in anesthetized patients. Ain Shams J Anaesthesiol 2014;7:96-100.

22. El-Ramely M, Mahmoud A, Abdelbaq M. The dual mode of ventilation ‘pressure-controlled ventilation-volume guaranteed’ does not provide anymore benefit in obese anesthetized patients. Egypt J Cardiothorac Anesth 2015;9:39-45.