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Original Article

Comparison of volume-controlled and pressure-controlled ventilation during laryngeal mask airway anesthesia in cataract surgery

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Abstract

Introduction: Most patients undergoing eye surgery are elderly adults with underlying cardiovascular diseases. One of the complications during recovery is gastric insufflation, which can cause detrimental effects on cardiovascular patients. The present study compares two methods of volume-controlled ventilation (VCV) and pressure-controlled ventilation (PCV).

Methods: The study enrolled 81 patients undergoing cataract surgery (41 in the PCV group and 40 in the VCV group). According to the American Society of Anaesthesiologists (ASA) classes I and II received general anaesthesia and laryngeal mask airway (LMA) ventilation using VCV or PCV. Maximum pressure (P_{peak}), dynamic compliance, expiratory tidal volume, Spo2, non-invasive blood pressure, heart rate, and pain in the epigastrium and umbilical region were monitored at intervals of 1, 5, 10, and 20 minutes after the initiation of anaesthesia and the results of two groups were compared.

Results: The means of P_{peak} and tidal volume in the PCV group as well as the means of dynamic compliance and end-tidal carbon dioxide (EtCO2) in the VCV group were significantly high. The mean diastolic blood pressure was significantly different between two groups at 20th minute. There were no significant differences in heart rate, mean systolic blood pressure, arterial oxygen saturation, or abdominal pain between two study groups.

Conclusion: VCV had a lower P_{peak} and a higher dynamic compliance, but PCV had a larger tidal volume and lower EtCO2. There were no differences in terms of abdominal and umbilicus pain, as well as hemodynamic parameters, between two groups.

Introduction

Mechanical ventilation is required for patients undergoing surgery due to the anaesthetic effects of general anaesthesia on the respiratory system. Employing proper ventilation can significantly reduce the risk of postoperative complications and enhance the patient's prognosis.[1] Laryngoscopy and endotracheal intubation can result in tachycardia, hypertension, upper airway soft tissue damage, misplacement of the endotracheal tube in the oesophagus or major bronchus, and even death. Laryngoscopy and intubation complications prompted the development of devices that were very efficient and free of the complications associated with the endotracheal intubation. These devices are referred to as supraglottic airway (SGAs) devices, with the laryngeal mask airway (LMA) being the most frequently utilized device. LMA was frequently utilized to control the airway during short-term anaesthesia. SGAs are less invasive than endotracheal tubes but provide enough ventilation for the sedated patient. LMA provides a more stable condition by minimizing the physiological reactions of patients during the implantation and removal of the device.[2,3]

Despite the mentioned benefits, LMA provides little protection against air entry into the stomach and results in gastric insufflation at the end of anaesthesia. This raises the risk of vomiting and lung aspiration, as

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well as intestinal distention in individuals regaining consciousness following anaesthesia.[3,4]

Thanks to technological advancements, various forms of ventilation are now being used in operation rooms during general anaesthesia. Two extensively used techniques are LMA with pressure-controlled ventilation (PCV) and volume-controlled ventilation (VCV).[5] It is worth noting that PCV and VCV are not two distinct modes of ventilation, but rather two distinct modes of ventilation control.[5]

By precisely managing the tidal volume, VCV enables improved control of EtCO2. Tidal volume and number of breaths are determined using this method, and the parameters relating to the pressure in each breath might vary based on the conditions. On the other hand, PCV minimizes the risk of a sudden increase in airway pressure and allows for variable tidal volume delivered to the lungs in each breath. Thus, while PCV eliminates the risk of pressure-induced lung injury, it requires continual monitoring to ensure that the minute ventilation does not drop or rise dramatically.[5,6]

Nowadays, most eye surgeries are conducted under local anaesthesia, and in cases when general anaesthesia is required, SGA devices are utilized to manage the airway due to the brief duration of the anaesthesia and the low-risk nature of these surgeries. In elderly patients with eye diseases such as cataracts, the patient is more likely to develop physiologic disorders such as heart rate elevation and hypertension.[7-9] On the other hand, abdominal pain associated with gastric and intestinal insufflation is common in patients ventilated with supraglottic devices.[10] If the patient has underlying cardiovascular problems, this abdominal pain can result in elevated blood pressure and tachycardia. If it is not treated, it can result in cardiovascular events,[8-12] indicating that selecting an optimal ventilation method is critical for maintaining hemodynamic stability. Thus, the goal of this study was to compare the two techniques of VCV and PCV in terms of ventilation, hemodynamics, and gastric insufflation in patients following cataract surgery.

Methods

This descriptive-analytic cross-sectional study examined 81 individuals aged 20–70 years who were candidates for cataract surgery and fell into ASA classes I and II. The procedures were conducted in accordance with the Helsinki Declaration-2013. After receiving informed consent, patients were separated into two groups (the first group of 41 and the second group of 40). Patients undergone surgery under local anaesthesia, patients with lung disease, patients with a body mass index (BMI) greater than 30, patients with obstructive sleep apnea, patients with a history of gastroesophageal reflux disease, patients with mental disorders, and patients with a cardiac pacemaker were excluded.

All patients were given midazolam 1 mg, fentanyl 1 μg/kg, propofol 2 mg/kg, and atracurium 2 mg/kg for induction of anaesthesia. Confounding variables such as the type of anaesthesia machine, ventilator settings, and laryngeal mask type were equated in two groups. All patients were sedated using a MEDEC Saturn Evo anaesthetic machine. To maintain airway control, different sizes of LMA classic were employed according to the patient's weight. Size 4 was used for patients weighing 50–70 kg, while size 5 was suitable for patients weighing 70–100 kg. After positioning the LMA cuff, it was inflated with the air by syringe to ensure that no air leakage occurred between 40 and 60 cmH2O of cuff pressure. To maintain anaesthesia, isoflurane MAC of 1 and a mixture of 50% oxygen and N2O were utilized. Pulse oximetry, electrocardiography, non-invasive blood pressure measurement, and capnography were performed on all patients. VCV began with a tidal volume of 8 mL/kg based on ideal body weight and a respiratory rate of 8-10 per minute in the first group. The number of breaths was then adjusted as needed based on capnography and to keep EtCO2 between 30 and 35 mm Hg. In the PCV group, the maximum airway pressure was adjusted to deliver the tidal volume of 8 mL/kg to the patient's lungs based on the ideal body weight. After starting with 8 to 10 breaths per minute, the respiratory rate was adjusted as needed based on capnography and to maintain EtCO2 between 30 and 35 mm Hg. An anaesthesiologist recorded peak pressure (P_{peak}), dynamic compliance, expiratory volume, Spo2 (pulse oximetry), non-invasive blood pressure, and heart rate of all patients at intervals of 1, 5, 10, and 20 minutes after the initiation of anaesthesia. The parameters were recorded using the information shown by the MEDEC Saturn Evo anaesthetic machine. The patient was moved to recovery following anaesthesia and reawakening. After regaining consciousness, the patient was asked if he/she felt any pain in the epigastrium and the umbilical region. Another anaesthesiologist entered he patient's response in the questionnaire as yes or no.

Statistical analysis

Data was collected and put into SPSS 20 software. The t-test was used to evaluate parametric data with a normal distribution, the X2 test or Fisher exact test was used to analyze non-parametric data, and the ANOVA test was used to analyze data with the repeated measures. The Kolmogorov-Smirnov test was used to determine the normality of the data distribution. In this study, *P* value of less than 0.5 was considered statistically significant.

Results

The present study examined 81 patients undergoing cataract surgery in two groups of VCV and PCV. There were no statistically significant differences between two groups in terms of gender ($P = 0.21$), weight ($P = 0.259$), age ($P=0.43$), and BMI ($P=0.09$; Table 1).

The difference in mean P_{peak} was statistically significant between VCV and PCV groups in the first minute (14.44 ± 5.24 cm H_2O vs 16.65 ± 1.85 cm H_2O, $P=0.014$) and the fifth minute (13.90 ± 4.90 vs 16.42 ± 1.99, $P=0.003$). The differences in all 4 groups are statistically significant ($P>0.05$ in all) (Figure 1 and Table 2).

The differences in mean dynamic compliance between VCV and PCV groups in the first minute (42.15 ± 8.63 vs 32.62 ± 7.82, $P<0.001$), fifth minute (41.78 ± 8.89 vs 13.90 ± 6.99, $P<0.001$), tenth minute (42.02 ± 9.12 vs 34.85 ± 7.93, $P<0.001$), and twentieth minute (41.68 ± 9.22 vs 34.05 ± 7.07, $P<0.001$) were statistically significant (Figure 2, Table 2).

The differences in the tidal volume between VCV and PCV groups in the fifth minute (506.58 ± 88.79 vs 550.50 ± 99.93 $P=0.04$), and tenth minute (503.41 ± 90.54 vs 555.25 ± 108.57, $P=0.022$) were statistically significant, but in the first minute ($P=0.192$) and twentieth minute ($P=0.122$) no statistically significant difference was observed (Figure 3 and Table 2).

The differences in SpO2 were not statistically significant between the two groups in the first minute ($P=0.532$), fifth minute ($P=0.411$), tenth minute ($P=0.373$), and twentieth minute ($P=0.277$) (Table 2).

The differences in EtCO2 between VCV and PCV groups in the fifth minute (35.70 ± 4.66 vs 32.68 ± 3.57, $P=0.002$), tenth minute (35.78 ± 4.73 vs 32.72 ± 2.58, $P=0.001$), and twentieth minute (35.73 ± 4.45 vs 32.85 ± 3.08, $P=0.001$) were statistically significant, but this difference was not significant in the first minute ($P=0.081$) (Table 2).

There were no statistically significant differences in systolic pressure between the two groups in the first minute ($P=0.547$), fifth minute ($P=0.981$), tenth minute ($P=0.060$), and twentieth minute ($P=0.091$) (Table 2).

Diastolic blood pressures were significantly different between VCV and PCV groups in the twentieth minute (71.49 ± 10.39 vs 77.35 ± 10.40, $P=0.013$) but these differences in the first minute ($P=0.515$), fifth minute ($P=0.295$), and tenth minute ($P=0.09$) were not significant (Table 2).

Heart rates were not statistically significant between two groups in the first minute ($P=0.148$), fifth minute ($P=0.438$), tenth minute ($P=0.598$), and twentieth minute ($P=0.894$) (Table 2).

Pain was reported by five patients in the VCV group (12.2%) and five patients in the PCV group (12.5%), indicating that there was no statistically significant difference between two groups in this variable ($P=0.967$) (Table 1).

Discussion

Supraglottic device ventilation has significant advantages over endotracheal tube ventilation,[13] as evidenced by numerous studies, and its use in short-term operations such as cataract surgery has expanded dramatically in recent years. Because patients with diseases like cataracts are more likely to develop metabolic disorders including cardiovascular difficulties and hypertension as they

Table 1. Demographic characteristics of the studied groups

		VCV	PCV	*P* value[a]
Female(%)		21(51.2%)	15(37.5%)	0.214
Age		64.34 ± 14.83	61.92 ± 12.53	0.430
Weight		63.80 ± 12.75	66.65 ± 11.24	0.259
Height		159.59 ± 12.51	167.25 ± 6.63	0.489
BMI		25.29 ± 4.34	23.78 ± 3.55	0.091
Pain	Yes	36(87.8%)	5(12.2%)	0.967
	No	35 (87.5%)	5(12.5%)	

Data are mean ± SD.
BMI, body mass index; VCV, Volume-controlled ventilation; PCV, pressure-controlled ventilation.
[a] Difference is significant at the < 0.05 levels (2-tailed).

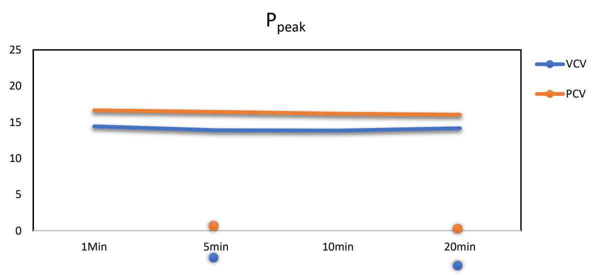

Figure 1. Comparison of mean P_{peak} between the two groups

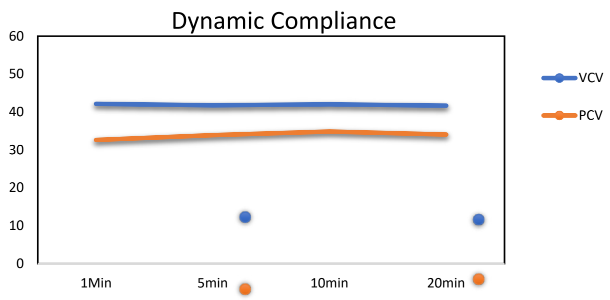

Figure 2. Comparison of the mean dynamic compliance between the two groups

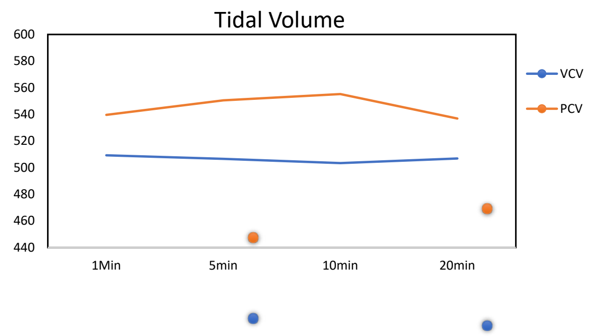

Figure 3. Comparison of mean tidal volume between the two groups

Table 2. comparison of studies variable between the two groups

	T1			T2			T3			T4		
	VCV	PCV	*P* value	VCV	PCV	*P* value	VCV	PCV	*P* value	VCV	PCV	*P* value
Ppeak	14.44 ± 5.24	16.65 ± 1.85	0.014	13.9 ± 4.90	16.4 ± 1.99	0.003	13.85 ± 4.90	16.17 ± 2.27	0.008	14.17 ± 5.1	16.05 ± 2.49	0.0.039
Dynamic Compliance	42.15 ± 8.63	32.62 ± 7.82	< 0.001	41.78 ± 8.89	33.90 ± 6.99	< 0.001	42.02 ± 9.12	34.85 ± 7.93	< 0.001	41.68 ± 9.22	34.05 ± 7.07	< 0.001
Tidal Volume	509.27 ± 96.73	539.62 ± 11.12	0.192	506.58 ± 88.79	550.50 ± 99.93	0.04	503.41 ± 90.54	555.25 ± 108.57	0.022	503.83 ± 87.01	536.87 ± 86.16	0.122
SpO2	99.56 ± 0.78	99.45 ± 0.81	0.532	99.47 ± 0.78	99.60 ± 0.91	0.411	99.36 ± 0.91	99.55 ± 0.93	0.373	99.32 ± 1.06	99.57 ± 1.06	0.277
EtCO2	35.36 ± 4.83	33.55 ± 4.41	0.081	35.70 ± 4.66	32.68 ± 3.57	0.002	35.78 ± 4.73	32.72 ± 2.58	0.001	35.73 ± 4.45	32.85 ± 3.08	0.001
Systolic blood pressure	112.29 ± 21.8	109.32 ± 22.3	0.574	116.41 ± 23.26	116.30 ± 22.33	0.981	114.32 ± 19.01	122.35 ± 18.87	0.060	114.27 ± 19.0	122.25 ± 22.8	0.091
Diastolic blood pressure	71.53 ± 12.63	69.60 ± 13.99	0.515	73.15 ± 11.99	75.95 ± 11.95	0.295	72.49 ± 11.54	77.62 ± 15.10	0.090	71.49 ± 10.39	77.35 ± 10.40	0.013
Heart Rate	73.29 ± 13.84	68.52 ± 15.43	0.148	71.32 ± 12.90	69.12 ± 12.40	0.438	69.56 ± 12.14	68.22 ± 10.50	0.598	38.7 ± 12.54	67.72 ± 10.84	0.894

VCV, Volume-controlled ventilation; PCV, pressure-controlled ventilation; T1, first minute; T2, Fifth minute, T3, Tenth minute, T4, Twenty minutes.
Data are mean ± SD.
Difference is significant at the < 0.05 levels.

become older,[9] choosing the right method of ventilation control to maintain hemodynamic circumstances is critical. However, there is still no clear criteria for selecting the best LMA ventilation control mechanism mode.[7,8,14]

The findings of the present study revealed that P_{peak} was higher in the PCV group than in the VCV group. However, as compared to VCV, several studies have found that the PCV technique reduces airway pressure.[15,16] Since some research suggested that PCV reduces airway pressure and lung damage in ARDS patients, the trend to employ it has grown.[17,18] PCV is still favored by many anaesthesiologists in patients with respiratory difficulties because it reduces airway pressure.[19] The current study, however, did not confirm this benefit in cataract patients. De Baerdemaeker et al failed to demonstrate the superiority of PCV over VCV in controlling P_{peak} in the lungs in a study on obese patients undergoing bariatric endoscopic surgery.[19]

The PCV group had a higher tidal volume than the VCV group in our study. Some studies found no difference in this regard between the two groups of PCV and VCV,[15,20,21] while others found that the VCV approach has a higher tidal volume than PCV.[16] It appears that more research is needed in this area.

Based on our findings, VCV has a higher dynamic compliance than the PCV which was in direct contrast to Lee and colleagues findings.[16] Cadi et al, on the other hand, found no difference in this variable between two procedures in their research on laparoscopic obesity surgery patients.[21]

The results of the present study showed that EtCO2 was lower in PCV than VCV, but Unzueta et al, in a similar study on thoracic surgery patients could not report a difference in this regard between two surgical methods.[22]

There was no difference between two groups in term of abdominal pain in this study. In pediatric patients, Keidan et al failed to find a difference in stomach issues between PCV and VCV.[20] In addition, there was no difference between two approaches in managing hemodynamic parameters such as systolic and diastolic blood pressure, heart rate, and SpO2. Unzueta et al found no difference in the mentioned variables between PCV and VCV in their research on thoracic surgery patients.[22]

There were several limitations to this study including the small number of samples studied, the impossibility of blinding, and the control of hemodynamic conditions only by non-invasive methods.

Conclusion

VCV had less P_{peak} and better dynamic compliance than PCV. In contrast, the PCV method had a higher tidal volume than the VCV method and at the same time was lower in EtCO2 than VCV. There was no difference between the two groups in terms of pain in the abdomen

Study Highlights

What is current knowledge?

- Most patients undergoing eye surgery are elderly adults with underlying cardiovascular diseases. One of the complications during recovery is gastric insufflation, which can cause detrimental effects on cardiovascular patients.

What is new here?

- There was no difference between the two groups in terms of pain in the abdomen and region and hemodynamic conditions.

and region and hemodynamic conditions.

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Competing Interests
The authors stated that they had no conflict of interest.

Ethical Approval
This study was approved by the Regional Committee of Ethics in Research (Human Subjects Studies) under the code IR.TBZMED.REC.1398.099.

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