ORIGINAL RESEARCH PAPER

Anaesthesiology

COMPARISON OF VOLUME CONTROL VENTILATION (VCV) AND PRESSURE CONTROL VENTILATION (PCV) MODES DURING LAPROSCOPIC CHOLECYSTECTOMY.

KEY WORDS: Cholecystectomy, PCV, VCV, PLMA, Pnemoperitonium

Dheeraj Kapoor	Associate Professor Department of Anaesthesia and Intensive Care, Govt. Medical College and Hospital, Chandigarh-160030, India
Kiran Bhatia*	Associate Professor Department of Anaesthesia and Intensive Care, ShaheedHasan Khan Mewati Govt. Medical College, Nalhar, Mewat, Haryana.*Correspondence Author
Jasveer Singh	Associate Professor Department of Anaesthesia and Intensive Care, Govt. Medical College and Hospital, Chandigarh-160030, India
Kanav Goyal	MBBS, Ex-Intern Department of Anaesthesia and Intensive Care, Govt. Medical College and Hospital, Chandigarh-160030, India
Shraddha Sinha	DA, DNB (Anaesthesia), Associate Consultant, Fortis Hospital, Mohali, India
Meghana Srivastava	DNB (Anaesthesia), Anaesthesia Specialist, Princess of Wales Hospital, 60 White Ct, Bridgend CF31 1LD, United Kingdom

ABSTRACT

Objectives To compare the parameters using VCV and PCV modes of ventilation with the use of PLMA as an airway device, in adult patients undergoing laparoscopic cholecystectomy:

Methodology The patients were randomly allocated to one of the two study groups (VCV and PCV groups PLMA device will be prepared for insertion with cuff deflated .

The patients will be allocated to one of following groups:

Group: I (n=30) those in which VCV mode of ventilation will be used

Group: II (n= 30) those in which PCV mode of ventilationwill be used

Results There were no significant differences in patient characteristics and co-morbidity in the two groups. Mean pH, PaO_2, SaO_2, and the PaO_2/FIO_2 ratio were higher in the PCV group, whereas $PaCO_2$ and the E CO_2–$PaCO_2$ gradient were lower (all $P<0.05$). Ventilation variables, including plateau and mean airway pressures, anaesthesia-related variables, and postoperative cardiovascular variables, blood gases, and morphine requirements after the operation were similar.

Conclusion. PCV compared with VCV during anaesthesia for laparoscopic cholecystectomy improves gas exchanges without increasing ventilation pressures or causing any haemodynamic side-effects. . In addition, using PCV routinely requires a good knowledge of its operating principles and a careful setting of the alarm limits .

Introduction

Laparoscopic surgery is supposed to be a safe, minimally invasive technique with a wide range of clinical applications. However, certain physiological changes are seen on creation of pneumoperitoneum, resulting in decreased dynamic lung compliance and elevation of peak inspiratory pressure(PIP), plateau pressure(PPlat) and end-tidal carbon dioxide tension ($EtCO_2$). The anaesthesiologist usually changes the respiratory rate (RR), tidal volume, or changes the mode from volume-controlled (VC) to pressure-controlled (PC) ventilation in order to limit increase in PIP. [1]

Pressure-controlled ventilation (PCV) is now a frequently used mode in the operating room in order to manage patients with elevated peak airway pressure.The tidal volume is delivered faster through this as compared to that in volume-controlled ventilation (VCV) mode. Moreover, they also have different gas distributions and a high and decelerating inspiratory flow. These characteristics of PCV compensates for any potential reduction in ventilation caused by a pressure limitation. Although both VCV and PCV modes have been used to ventilate patients undergoing different laparoscopic surgeries under general anaesthesia, the decelarating inspiratory flow used in PCV generates higher instantaneous flow peaks and an improved alveolar recruitment, thus improving oxygenation without any haemodynamic side-effects. [2]

Several supraglottic airway devices have been used as alternatives to endotracheal tubes with either spontaneousor positive pressure ventilation. It has been seen that proseal laryngeal mask airway (PLMA) provides higher sealing pressure and more effective ventilation than the classic LMA (CLMA) during laparoscopic cholecystectomy. However, at present no studies have been published to compare the effects and application of VCV and PCV modes on respiratory dynamics using PLMA in during laparoscopic cholecystectomy surgery. We therefore, aim to compare the pulmonary mechanics, gas exchange and haemodynamic responses during VCV and PCV modes using PLMA in patients undergoing laparoscopic cholecystectomy surgery.

METHODOLOGY

The present study will be conducted in the Department of Department of Anaesthesia and intensive care govt. Medical College & Hospital, Chandigarh After the approval of protocol by the Hospital Ethics Committee and obtaining informed consent from the patient, a total number of 60 patients will be included.

Inclusion criteria

1. Age group: 18 - 60 years
2. BMI <30 kg/ m2
3. American Society of Anesthesiologist (ASA) physical status I and II
4. Patients scheduled for elective laparoscopic cholecystectomy

Exclusion criteria

1. Patients' refusal or inability to give informed consent.
2. American Society of Anesthesiologist (ASA) ≥3 physical status of either sex
3. Upper respiratory tract infection
4. Anticipated difficult airway
5. Patients at increased risk of aspiration -gastro esophageal reflux disease, non fasting status, pregnancy
6. Cardiorespiratory or cerebrovascular disease
7. Diabetes Mellitus
8. History of allergy to any drug

Study design: Prospective, randomised, double blind study

Grouping of patients

The patients will be randomly allocated to one of the two study groups(VCV and PCV groups) using sequential random number table. Anaesthesiologists with more than six months experience with airway management using laryngeal masks and at least 20 successful insertions of PLMA will administer anaesthesia and will do ventilator settings according to the group allocation. Second anaesthesiologists will be available to record data as an independent observer. An appropriately sized (size 3 for patients weighing 30- 50 kg, size 4 for those between 50 - 70kg, size 5 for those between 70-100kg) PLMA device will be prepared for insertion with cuff deflated completely and shaped with its dorsal surface lubricated with a water soluble jelly.

The patients will be allocated to one of following groups:
Group: I (n=30) those in which VCV mode of ventilation will be used

Group: II (n= 30) those in which PCV mode of ventilationwill be used

All patients will receive a standardized general anaesthesia technique. Neuromuscular blockade would be achieved with vecuronium 0.1 mg/kg and patient's lungs would be manually ventilated for over 3 minutes followed by insertion of PLMA. Anaesthesia will be maintained with 50% oxygen in air, propofol infusion (rate of 100-300 μg/kg/min)and this was adjusted to keep the BIS values between 45 and 60.Neuromuscular blockade will be assured by intermittant doses of 0.02 mg/kg IV of vecuronium bromide. Analgesia will be supplemented with incremental doses of fentanyl 20 μg if required, to maintain the haemodynamic parameters within 20% of the baseline.

Successful placement will be confirmed by the occurrence of a square wave trace on the capnograph during manual ventilation. Mechanical ventilation will be done. Once PLMA insertion is achieved, the oropharyngeal cuff leak pressures will be obtained by closing the expiratory valve of the anesthesia circuit with a fixed gas flow rate of 3 L/min and noting the airway pressure at which equilibrium will be reached.The airway pressure will be not allowed to exceed 40 cm H2O. After measurement of the OLP, intermittent positive pressure ventilation will be restarted.

In the VCV group, baseline ventilation of the lungs will be done with volume-controlled ventilation and a tidal volume of 10 ml/kg ideal body weight (IBW). The initial respiratory rate of 12 breaths per minute, inspiratory to expiratory ratio of 1:2 and a positive end-expiratory pressure (PEEP) of 5 cm of H2O, will be adjusted during laparoscopy to maintain an EtCO2 of 30-35 mmHg. Five minutes after PLMA insertion and mechanical ventilation, the first blood samples from the radial artery will be taken for blood gas analysis followed by peritoneal insufflation.

In the PCV group, baseline ventilation of the lung will be done with pressure-controlled ventilation, and this will be initiated with a peak airway pressure that will provide a tidal volume of 10 ml/kg IBW with an upper limit of 35 cmH2O. In both groups, a CO2 pneumoperitoneum will be induced with a maximal intra abdominal pressure of 15 mmHg and reverse-Trendelenberg position with 20° head up angulation.Then second blood gas analysis will be done after creation of surgical position.The EtCO2, peak airway pressure (Ppeak), leak pressure, mean airway pressure, compliance, airway resistance and SpO2 will be continuously monitored during the procedure and recorded at various time points (T1: 5minutes after insertion of the laryngeal airway, T2: 5 minutes after CO2 insufflation and T3: after making surgical position, T4: 5 minutes after deflation of puemoperitoneum). The P peak, the leak pressure, the mean airway pressure, the compliance and the airway resistance will be measured by built-in spirometer of anaesthesia work station.

At the end of surgery, all the patients will receive diclofenac sodium 1 mg/kg (slow intravenous infusion in 30 minutes) and ondansetron 0.1 mg/kg IV, to reduce pain and emesis, respectively. Airway device will be removed, when the patient is awake and resumed spontaneous breathing. Patient will than be extubated and shifted to postanaesthesia care unit.

OBSERVATION TABLES

TABLE 1: PATIENT CHARACTERISTICS.

	PCV (n=30)	VCV (n=30)
Age (yr)	40 (9) (27–61)	40 (12) (23–62)
Weight (kg)	121 (21) (85–180)	119 (17) (96–160)
Height (m)	1.65 (0.09) (1.52–1.79)	1.64 (0.09) (1.50–1.83)
BMI (kg m^{-2})	44 (5) (36–56)	44 (5) (38–55)
Ideal weight (kg)	57 (8) (45.1–73)	57 (9) (43–78)
Body surface area (m^2)	2.35 (0.25) (1.90–2.99)	2.32 (0.20) (2.06–2.75)

TABLE 2 PREOPERATIVE TESTS.

	PCV	VCV
FEV1 (litre s^{-1})	3 (0.8) (1.7–5)	3 (0.8) (1.9–5.3)
FVC (litre)	3.5 (0.9) (2.1–5.1)	3.4 (0.95) (2.1–5.8)
FEV1/FVC	84 (3) (78–89)	85 (5) (77–93)
TLC (litre)	5 (1.2)* (3–7.5)	5 (1.1)† (3.3–6.6)
pH	7.42 (0.02) (7.40–7.5)	7.41 (0.02)†(7.40–7.44)
PaO_2 (kPa)	11.7 (1.3)† (9.2–14.9)	11.7 (1.8)§ (9.4–16.0)
$PaCO_2$ (kPa)	5.2 (0.5) (4.1–6.0)	5.3 (0.4)† (4.5–6.2)
SaO_2 (%)	98 (1)* (96–99)	98 (1)† (95–100)

TABLE 3 INTRAOPERATIVE VENTILATION VARIABLES.

	PCV (n=30)	VCV (n=30)	P-value
Tidal volume (Vt) (ml)	613 (91) (481–858)	573 (81) (430–700)	NS
Vt ml kg^{-1} ideal wt	11 (1.4) (8.8–13.2)	10.2 (1.2) (8.13–12.43)	NS
Minute volume (litre min^{-1})	10.9 (1.8) (7.2–15.5)	10.6 (1.8) (8.3–14.2)	NS
Peak inspiratory flow (litre s^{-1})	52 (7) (39–63)	41 (7) (32–57)	<0.01[†]
SpO2 (%)	99 (1) (97–100)	98 (3) (93–100)	NS
Dead space (ml)	189 (27) (114–244)	176 (26) (132–217)	NS
VCO2 (ml min^{-1})	276 (51) (191–360)	275 (57) (195–366)	NS

Mean (SD) (range). PCV, pressure-controlled ventilation; VCV, volume-controlled ventilation; Ti, inspiratory time; E CO_2, end-tidal CO2; VCO_2, carbon dioxide output; VO2, oxygen delivery; PAO_2, partial pressure of oxygen in alveoli. *Mann–Whitney test; [†]t-test; [‡]n=17Values for haemodynamic variables were similar in both groups intraoperatively and after operation .

TABLE 4: HAEMODYNAMIC VARIABLES IN THE TWO GROUPS.

	Intraoperative		Postoperative	
	PCV	VCV	PCV	VCV
Systolic arterial pressure (mm Hg)	131 (21) (100–180)	119 (22) (88–159)	129 (16) (105–160)	127 (21) (95–187)
Diastolic arterial pressure (mm Hg)	81 (16) (49–104)	76 (15) (54–102)	76 (12) (52–94)	79 (15) (53–109)
Mean arterial pressure (mm Hg)	96 (17) (67–125)	89 (16) (66–115)	98 (16) (71–138)	94 (19) (66–136)
Heart rate (beats min^{-1})	84 (15) (57–117)	77 (14) (46–101)	76 (16) (50–111)	76 (18) (40–111)

There was no difference in dynamic compliance and airway resistance, dead-space, dead space-to-tidal volume ratio, and CO2 output. The alveolar-to-arterial oxygenation gradient was lower in the PCV group than in the VCV group (28.5 vs 34.9 kPa, P<0.05).

Volume-7 | Issue-1 | January-2018 | PRINT ISSN No 2250-1991

TABLE 5 INTRAOPERATIVE AND POSTOPERATIVE VARIABLES

	Intraoperative			Postoperative		
	PCV	VCV	*P*-value	PCV	VCV	*P*-value
pH	7.40 (0.03)[a] (7.34–7.46)	7.38 (0.02) (7.33–7.43)	0.041	7.36 (0.02) (7.32–7.40)	7.36 (0.05) (7.20–7.40)	NS
PaO_2 (kPa)	22.5 (8.5)* (13.1–40.2)	15.9 (5.9) (8.4–28.9)	0.011	16.1 (5.2) (9.5–30.1)	14.8 (4.5) (8.3–24.8)	NS
$PaCO_2$(kPa)	5.2 (0.4) (4.4–6.0)	5.4 (0.3) (5.2–6.0)	0.014	5.9 (0.4) (5.0–6.7)	6.0 (1.2) (5.2–10.0)	NS
SaO_2 (%)	99 (1)* (98–100)	98 (2) (92–100)	0.010	98 (2) (94–100)	98 (2) (92–100)	NS
TCO_2(mmol $litre^{-1}$)	25 (1) (22–28)	25 (2) (22–28)	NS	26 (1) (24–28)	26 (2) (23–30)	NS
PaO_2 (in mm Hg)/FIO_2	281 (107) (163–503)	199 (74) (105–362)	0.011			

Arterial blood gases in the two groups; mean (SD) (range). PCV, pressure-controlled ventilation; VCV, volume-controlled ventilation; FIO_2, fraction of inspired oxygen; TCO_2,.. After operation, there were no significant differences between the two groups. One patient suffered from respiratory acidosis with a pH value of 7.20 and PaCO2 10 kPa; this was considered to be due to morphine.After 2 h in the recovery room, nasal oxygen requirements were similar [mean (SD) (range) 2 (2) (0–4) litre min^{-1} for PCV and 3 (2) (0–9) litre min^{-1} for VCV], as were total morphine doses [8 (7) (0–20) mg for PCV and 7 (6) (0–20) mg for VCV].

RESULTS

There were no significant differences in patient characteristics and co-morbidity in the two groups. Mean pH, PaO2, SaO2, and the PaO2/FIO2 ratio were higher in the PCV group, whereas PaCO2 and the E CO2–PaCO2 gradient were lower (all $P<0.05$). Ventilation variables, including plateau and mean airway pressures, anaesthesia-related variables, and postoperative cardiovascular variables, blood gases, and morphine requirements after the operation were similar.

STATISTICAL ANALYSIS

Sample size was estimated based on previous studies . Our sample size came out to be 25 subjects per group at a power of 80 % & confidence interval of 95 %. For possible dropouts, it was decided to include extra subjects so finally it was decided to include 30 subjects per group.

Discrete categorical data will be represented in the form of either a number or a percentage continuous data, assumed to be normally distributed, will be written as either in the form of its mean and standard deviationor in the form of its median and interquartile range, as per the requirement. Student t-test or Mann Whitney U test will be applied to compare 2 groups depending upon the normality of the data. Proportions will be compared using Chi square or Fisher's exact test, depending on their applicability for 2 groups.. For comparison (time related variables) of Hemodynamics Repeated Measure ANOVA will be applied. All the statistical tests will be two-sided and will be performed at a significance level of α=.05 . Analysis will be conducted using IBM SPSS STATISTIC.

DISCUSSION

This study comparing VCV and PCV using two different algorithms to set mechanical ventilation during laparoscopic gastric banding in obese patients has shown differences in arterial blood oxygenation (PaO_2 and SaO_2) and ventilation variables (pH and $PaCO_2$) in favour of the PCV mode. These differences emerged although plateau pressures were similar in the two groups. These pressures reached 26 cm H_2O with both VCV and PCV when providing sufficient MV for CO_2 removal in all of our patients, substantiating the existence of ventilation problems in obese patients as previously reported.

Davis K Jr et al did comparison of volume control and pressure control ventilation.Their study was similar to our study. The mean PaO_2 (in mm Hg)/FIO_2 ratio in the VCV group was under 200 in these patients, with normal preoperative pulmonary function tests and blood gases, further signifying the perioperative impairment in respiratory function in these patients. Different ventilation strategies, including PEEP or high Vt, with variable effects have been proposed to improve oxygenation during laparoscopic surgery. Recruitment manoeuvres have been shown to be effective intraoperatively.[4]

To explain the higher PaO_2 values for the same Vt using the PCV mode, higher plateau pressures could have been expected, but this was not the case in our study. We calculated the mean airway pressure from our data recordings which is a key variable in alveolar gas exchange. It is related to mean alveolar pressure and is used to assess total lung volume. We found no difference in mean airway pressure between VCV and PCV for identical MV, PEEP, pneumoperitoneum, and plateau pressure values. Furthermore, metabolic acidosis was not suspected in any patient and there was no difference in haemodynamics between the two groups as the haemodynamic variables, VCO_2, dead-space, and E CO_2 were similar.

Gupta SD et al aiso did comparison between volume-controlled ventilation and pressure-controlled ventilation in providing better oxygenation in obese patients undergoing laparoscopic cholecystectomy and demonstrated the absence of transoesophageal echocardiographic changes when switching from VCV to PCV during laparoscopic urological procedures. Oxygenation was not modified in this study but only 21 non-randomized non-obese patients were studied for 20 min of PCV, after VCV. [5]

Kim JY and colleagues did a prospective, randomized study effect of pressure- versus volume-controlled ventilation on the ventilatory and hemodynamic parameters during laparoscopic appendectomy in children . The increase that they found in the mean airway pressure [from 3.87 (1.86) to 5.03 (2.27) cm H_2O] in part explained the improvement in gas exchange but, because their decelerating insufflation mode did not have a pressure limit, the pressure–time curve was very different from the one observed in the PCV mode and it reached higher pressure values. However, we did not find any difference in mean airway pressure in this study. [6]

Cadi P et al did asimilar study in which they concluded that. pressure-controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled Ventilation . Their study compared a decelerating flow with a constant flow during inspiration ,found a significant increase in PaO_2 and a reduction in the dead space to tidal volume ratio and in the alveolar-to-arterial oxygenation gradient, while Vt, Ti, respiratory rate, and I/E ratio were kept unchanged. Their results are similar to ours except for the small changes in $PaCO_2$ in our study.[7]

Lu PP et al used ProSeal versus the classic laryngeal mask airway for positive pressure ventilation during laparoscopic cholecystectomy.Natalini G in their study used standard laryngeal mask airway and LMA-ProSeal during laparoscopic surgery.Both studies compared PCV with VCV during ventilation for surgery using a cross-over design and, similar to our study, found no differences in Vt and plateau pressures, but also in arterial oxygenation unlike the findings in our study.[8,9]

The PCV mode uses a decelerating inspiratory flow and provides the highest possible flow value. This option is available on all recent anaesthesia ventilators, even though only the models fitted with a piston or a turbine work in the same way as an intensive care ventilator.. However, an insufficient flow in the PCV mode can lead to a decrease in tidal volume. An intensive care ventilator able to generate a high enough flow (>150 litre min−1) to reach plateau pressure with a steep slope was therefore chosen for our obese patients. Similar observations were made by Dion JM et al .They saw that ventilation during laparoscopic-assisted bariatric surgery and volume-controlled, pressure-controlled or volume-guaranteed pressure-regulated modes. [10]

The three key determinants of PaO_2 are inspired oxygen pressure, alveolar ventilation, and ventilation/perfusion ratio. Since we set FIO2 at 0.6 for all patients, the reason for the difference in oxygenation between VCV and PCV would be a change in the lung ventilation/perfusion ratio.

For a given tidal volume, inspiratory flow reaches much higher values with the PCV than with the VCV mode. In our study, it was 52 litre min−1 in PCV group and 41 litre min−1 in VCV group. Consequently, 67% of the Vt was delivered at half inspiratory time (excluding plateau time) in PCV and 53% in VCV group. Thus, we hypothesize that for the highest flow in the PCV mode, mean airway and plateau pressures measured at the end of inspiration grossly underestimate the instantaneous regional pressures reached in the lungs at the beginning of insufflation. Alveoli with short time constant may be initially over inflated, but then a more homogeneous distribution of the Vt in all the ventilated alveoli could follow, reducing the amount of atelectasis by an improved alveolar recruitment. Furthermore, even if inspiratory flow is very low at the end of inspiration in PCV, only in VCV it drops to zero during the whole plateau time.

Balick-Weber CC et al like our study did respiratory and haemodynamic effects of volume-controlled vs pressure-controlled ventilation during laparoscopy. They did a cross-overstudy with echocardiographic assessment .The better preserved ventilation/perfusion ratio during PCV mode is marked by a difference in the alveolar-to-arterial oxygenation gradient; in our study, this was 28.5 kPa in the PCV group and 34.9 kPa in the VCV group. Also, differences in the E CO2–PaCO2 gradient, pH and PaCO2 in the two groups, despite the similar values for MV, support the hypothesis of a better ventilation/perfusion ratio in the PCV group.[11]

Jeon WJ et al did comparison of volume-controlled and pressure-controlled ventilation using a laryngeal mask airway during gynecological laparoscopy .Extending sufficiently the plateau time in VCV, and thus increasing inspiratory flow, might provide the same effects on gas exchange as those observed in PCV.Each patient had high intraoperative PaO2 values in our study but the supplemental amount of oxygen given by PCV gives the anaesthesiologist some more security in the obese patient whose non-hypoxic apnoea duration is very short.[12]

Tuğrul M et al in their study did comparison of volume controlled with pressure controlled ventilation during one-lung anaesthesia The absence of difference in the postoperative PaO2 measurements can be explained by postoperative atelectasis due to ventilation with an FIO2 set to 1.0 before extubation and to general anaesthesia which generates persistent atelectasis in the morbidly obese patients.Preoperative pulmonary function tests did not show any difference between the two groups. Only 13 of our patients underwent a metacholine test and sensitive patients did not receive preoperative treatment as a matter of routine. It is currently not clear whether obesity, bronchial hyper reactivity, and asthma are related.[13]

The limitations of this study are that it is single-blinded, it lacks invasive haemodynamic monitoring and that it could lack the power to detect a slight difference between MV and Vt between the two groups. Such a difference would not be important clinically.

CONCLUTION

In conclusion, PCV compared with VCV during anaesthesia for laparoscopic cholecystectomy improves gas exchanges without increasing ventilation pressures or causing any haemodynamic side-effects. . In addition, using PCV routinely requires a good knowledge of its operating principles and a careful setting of the alarm limits, particularly the MV and the Vt alarms; a sudden change in the patient's compliance could increase or lower those two variables

REFERENCES ;

1. Suh MK, Seong KW, Jung SH, and Kim SS. The effect of pneumoperitoneum and Trendelenburg position on respiratory mechanics during pelviscopic surgery. Korean J Anesthesiol 2010 November 59(5): 329-34.
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. Broach AN, Mansuria SM, Sanfilippo JS. Pediatric and adolescent gynecologic laparoscopy. Clin Obstet Gynecol 2009; 52: 380-9.
4. Davis K Jr, Branson RD, Campbell RS, Porembka DT. Comparison of volume control and pressure control ventilation: is flow waveform the difference? J Trauma1996; 41: 808-14.
5. Gupta SD, Kundu SB, Ghose T, Maji S, Mitra K, Mukherjee M et al.Comparison between volume-controlled ventilation and pressure-controlled ventilation in providing better oxygenation in obese patients undergoing laparoscopic cholecystectomy. Indian Journal of Anaesthesia,2012 May-June56(3): 276-82.
6. Kim JY, Shin CS, Lee KC, Chang YJ,Kwak HJ. Effect of Pressure- Versus Volume-Controlled Ventilation on the Ventilatory and Hemodynamic Parameters During Laparoscopic Appendectomy in Children: A Prospective, Randomized Study. Journal of laparoendoscopic & advanced surgical techniques 2011; 21(7).
7. Cadi P, Guenoun T, Journois D, Chevallier JM, Diehl JL and Safran D. Pressure-controlled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled Ventilation. British Journal of Anaesthesia 2008; 100 (5): 709–16.
8. Lu PP, Brimacombe J, Yang C, Shyr M. ProSeal versus the classic laryngeal mask airway for positive pressure ventilation during laparoscopic cholecystectomy. Br J Anaesth 2002; 88: 824-7.
9. Natalini G, Lanza G, Rosano A, Dell'Agnolo P, Bernardini A.Standard laryngeal mask airway and LMA-ProSeal during laparoscopic surgery. J Clin Anesth 2003; 15: 428-32.
10. Dion JM, McKee1 C,Tobias JD, Sohner P, Herz D, Teich S, et al. Ventilation during laparoscopic-assisted bariatric surgery: volume-controlled, pressure-controlled or volume-guaranteed pressure-regulated modes. Int J Clin Exp Med 2014;7(8):2242-47.
11. Balick-Weber CC, Nicolas P, Hedreville-Montout M,Blanchet P and Stephan F. Respiratory and haemodynamic effects of volume-controlled vs pressure-controlled ventilation during laparoscopy: a cross-overstudy with echocardiographic assessment. Br J Anaesth 2007; 99: 429–35.
12. Jeon WJ, Cho SY, Rang Bang M and Young Ko S. Comparison of volume-controlled and pressure-controlled ventilation using a laryngeal mask airway during gynecological laparoscopy. Korean J Anesthesiol 2011; 60: 167-72.
13. Tuğrul M, Camci E, Karadeniz H, Sentürk M, Pembeci K, Akpir K. Comparison of volume controlled with pressure controlled ventilation during one-lung anaesthesia. British journal of anaesthesia. 1997 Sep 1;79(3):306-10.