Original Article

Clinical Investigation-.Evaluation of Pressure Controlled Ventilation Versus Volume Controlled Ventilation with Peep on Respiratory Mechanics and Hemodyanmics in Patients of Laparoscopic Cholecystectomy

Alka Chandra, Lalit Samantaray, Shri Krishan Chand, Shaleen Bhardwaj and Hridya Dinesh

Department of Anesthesiology and Critical Care Hindurao Hospital, New Delhi, India

ABSTRACT

Introduction: The laparoscopic surgeries create pneumoperitoneum which has adverse hemodynamic and respiratory consequences. Several ventilatory strategies exist to prevent intra-operative atelectasis and improve arterial oxygenation in laparoscopic surgeries but they remain controversial. Application of PEEP (Positive end expiratory pressure) in mechanical ventilation during laparoscopic surgery provides beneficial effects on respiratory functions, prevents atelectasis and improves ventilation-perfusion mismatch. We performed this study to compare the effects of Pressure controlled ventilation (PCV) VS VCV (Volume controlled ventilation) with PEEP of 7 cmH_2o on lung mechanics and oxygenation parameters in patients undergoing laparoscopic cholecystectomy.

Materials and Methods: The study included a total of 98 patients allocated to PCV (Group A) and VCV (Group B) groups with 49 patients in each group. After intubation the patients were put on ventilatory settings chosen based on a specifically derived algorithm. Peak airway pressure (*P* peak), mean airway pressure (*P* mean), dynamic compliance, mean arterial pressure, PaO_2, $PaCo_2$, pH were noted at specific time intervals.

Results: The peak airway pressure was higher in group B compared to group A at T3-6. The mean airway pressure was higher in group A compared to B from T3-6. The dynamic compliance was better in group A compared to group B from T3-6. The PaO_2 measured at T2 and T4 was higher in group A, the $PaCo_2$ and pH were comparable in two groups. The hemodynamics were comparable in both groups at various time intervals.

Conclusion: PCV is a better mode of ventilation than VCV in patients of laparoscopic cholecystectomies**.**

Key Words: Laparoscopy, oxygenation, pressure-controlled ventilation, volume-controlled ventilation.

Received: 07 May 2024**, Accepted:** 10 September 2024

Corresponding Author: Alka Chandra**,** MD, Department of Anaesthesia and Critical Care, Hindurao Hospital and Ndmc Medical College. New Delhi, India. **Tel.:** +91-09560044454, **E-mail:** dralkadelhi@yahoo.co.in

ISSN: 2090-925X, 2024, Vol.16, No. 02

INTRODUCTION

Laparoscopic approach to surgery has become increasingly common because of several advantages including reduction in postoperative pain and a shorter hospital stay[1,2]. However, laparoscopy requires creation of a pneumoperitoneum which has certain adverse haemodynamic and respiratory consequences.

In the respiratory system, the raised intra-abdominal pressure due to pneumoperitoneum results in an elevated diaphragm, decreased functional residual capacity, and a fall in thoraco-pulmonary compliance of up to 30%[3]. These changes are associated with an increase in the peak airway pressure intra-operatively, making mechanical ventilation problematic during general anaesthesia. Not only do raised peak airway pressures pose a threat of macroscopic and microscopic barotrauma and volutrauma in the lungs, they make it difficult to maintain eucapnia and oxygenation within allowable airway pressure limits[4].

To limit the increase in peak airway pressure during conventionally used volume controlled ventilation (VCV), it is usual to alter the tidal volume and respiratory rate. Use of VCV during anesthesia is common and has been the only available mode on anesthesia ventilators for a long time. VCV does not limit the airway pressure since it utilizes a constant flow to deliver a preset tidal volume.

Pressure controlled ventilation (PCV) is a relatively lesser known ventilation strategy in the operating room. It has the advantage of limiting increase in peak airway pressure and thus compensating for any potential reduction in ventilation caused by high airway pressures . It uses a decelerating flow pattern with maximal flow at the beginning of inspiration until the set pressure is reached. This pattern results in a more homogenous distribution of the tidal volume, improving static and dynamic compliance[5,6].

DOI: 10.21608/ASJA.2024.287798.1105

Application of PEEP in mechanical ventilation during laparoscopic surgery provides beneficial effects on respiratory functions, prevents atelectasis and improves ventilation-perfusion mismatch [7]. Different levels of PEEP such as 5,7,10 have been shown to decrease intraoperative atelectasis, improve gas exchange and oxygenation without any hemodynamic and respiratory complications[8,9,10]. In a study it was suggested that PEEP at 7 cm H_2O might be optimal for improving Pao_2 without excessively increasing peak airway pressure or aggravating hemodynamic parameters a higher PEEP of 10 or more may lead to higher peak pressures and hemodynamic compromise with no additional benefits with respect to oxygenation[11].

The present trial was planned to evaluate and compare PCV and VCV with PEEP of 7 cm of H_2O on lung mechanics and oxygenation parameters in patients undergoing laparoscopic cholecystectomy.

MATERIALS AND METHODS

After obtaining approval from Institutional ethical committee this prospective randomized study was conducted in total 98 patients, allocated in two different groups: Group A with PCV mode and Group B with VCV mode. Patients with age between 18-60yrs, ASA I and II and BMI < 30KG/m2 posted for laparoscopic cholecystectomy were randomly divided into two groups using www.randomizer.com. Patients with anticipated or unanticipated difficult airway patient refusal for participation in the study, intraoperative usage of airway device other than endotracheal tube for airway maintenance, evidence of respiratory disease, conversion to laparotomy and continuation of mechanical ventilation in the post operative period were excluded from the study.

After attaching the standard monitors induction of anaesthesia was done with 2mic/kg fentanyl , 2mg/kg propofol till loss of verbal response following which tracheal intubation was performed after giving vecuronium 0.1mg/kg. Anaesthesia was maintained with a O_2:N_2O of 40 and 60 percent along with isoflurane of 1 MAC. In VCV group the tidal volume was initially set at 8ml/kg. In the PCV group the ventilator was adjusted so that a preset pressure attained the desired tidal volume (a variation of 5% was accepted). Respiratory rate was set at 12 breaths/minute in both the groups. The inspiratory:expiratory ratio of 1:2 and Fio_2 (.3) and PEEP of 7 cm H_2O was applied in all the patients. The respiratory rate was increased or decreased by 1/minute[mt] every 2 mts upto a maximum and minimum of 18 and 10 respectively to maintain $EtCo_2$ of 35 to 45 mm of Hg. If the target $EtCo_2$ was not achieved tidal volume was increased or decreased by 1ml /kg every 2 minutes upto a maximum and minimum of 10 and 6 ml/kg respectively in the VCV mode.

In the PCV mode pressure was increased or decreased by 1 cm H_2O and maximum pressure was limited to 35 cmH_2O. The Fio_2 was titrated upwards from 0.3 as required to maintain Spo_2 greater than 98%. Pneumoperitoneum was initiated with 12mmHg intra-abdominal pressure in all the patients in supine position followed by 15 to 30 degree head up position. Peak airway pressure (Ppeak), mean airway pressure(Pmean), dynamic compliance, HR, MAP, Sao_2 were measured at following intervals.

T1- 5 minutes after intubation.

T2- 10 minutes after intubation.

T3- 10 minutes after pneumoperitoneum.

T4- 20 minutes after pneumoperitoneum.

T5- 30 minutes after pneumoperitoneum.

T6- 10 minutes after release of pneumoperitoneum.

PaO_2, $PaCO_2$, PH values were measured at;

T2- 10 minutes after intubation.

T4- 20 minutes after pneumoperitoneum.

Statistical Analysis

Statistical analysis was performed by the SPSS program for Windows, version 17.0 (SPSS, Chicago, Illinois). Continous variables are presented as mean±SD, and categorial variables are presented as absolute numbers and percentage. Normally distributed continuous variables were compared using the unpaired t test, whereas the Mann-Whitney U test was used for those variables that were not normally distributed. Catergorical variables were analysed using either the chi square test or Fisher's exact test. Paired t test was used to compare difference within the groups from T1 to different points. *P value* less than 0.05 was considered statistically significant.

Observations and results

The dynamic complaince was higher in group A as compared with group B at all points of time intraoperatively. Statistically significant difference was noted from T3 to T6

RESULT

As shown in (Table 1) the age, weight, height and BMI was comparable in both the groups. The sex ratio was also comparable in both the groups with P=0.564. The Ppeak was found to be statistically higher in group B compared to group A at T3 ($P< 0.001$, T4 ($P< 0.001$), T5 ($P< 0.001$), T6 ($P< 0.001$) as shown in (Table 2). The mean airway pressure was found to be statistically higher in group A as compared to group B at T2 to T6 i.e ($P< 0.001$, $P< 0.001$, $P< 0.001$, $P< 0.001$ respectively) as shown in (Table 3).

Table 1: Age , weight, height, BMI distribution of study population

	Group A(n=49)	Group B(n=49)	*p value*
	Mean ± SD	Mean ± SD	
Age (Years)	32.82 ± 7.01	35.61 ± 10.20	0.117
Weight (Kg)	56.57 ± 8.03	57.22 ± 8.81	0.702
Height (Cm)	155.71 ± 5.70	157.61 ± 6.50	0.128
BMI (Kg/m^2)	23.31 ± 2.88	22.97 ± 2.79	0.554

Table 2: Ppeak in study population at different points of time

Ppeak (cmH_2O)	Group A(n=49)	Group B(n=49)	*p value*
	Mean ± SD	Mean ± SD	
T1	16.31 ± 1.46	16.82 ± 1.6	0.103
T2	16.61 ± 1.47	17.22 ± 1.81	0.069
T3	18.31 ± 1.61	20.43 ± 2.44	<0.001
T4	19.37 ± 1.99	21.39 ± 2.68	<0.001
T5	19.39 ± 1.86	21.55 ± 2.48	<0.001
T6	18.43 ± 1.59	20.16 ± 2.73	<0.001

Group A: PCV, Group B: VCV,Values expressed as Mean ± SD, $p < 0.05$ considered significant T1: 5 min post induction, T2: 10 min post induction, T3: 10 min post PNP, T4: 20 min post PNP, T5:30 min post PNP, T6:10 min post PNP.

Table 3: Pmean in study population at different points of time

Pmean (cm H_2O)	GroupA (n=49)	GroupB (n=49)	*p value*
	Mean ± SD	Mean ± SD	
T1	16.82 ± 1.6	16.31 ± 1.46	0.103
T2	17.22 ± 1.81	16.61 ± 1.47	0.069
T3	20.43 ± 2.44	18.31 ± 1.61	<0.001
T4	21.39 ± 2.68	19.37 ± 1.99	<0.001
T5	21.55 ± 2.48	19.39 ± 1.86	<0.001
T6	20.16 ± 2.73	18.43 ± 1.59	<0.001

Group A: PCV, Group B: VCV, Values expressed as Mean ± SD, $p < 0.05$ considered significant T1: 5 min post induction, T2: 10 min post induction, T3: 10 min post PNP, T4: 20 min post PNP, T5:30 min post PNP, T6:10 min post PNP

The mean airway pressure was higher in group A as compared with group B at all points of time intraoperatively. Statistically significant difference was noted from T3 to T6 .

Both the group A and B exhibited comparable exhaled tidal volume throughout the intra-operative course with no statistically significant difference at various interval. The Spo2 and $EtCO_2$ values between the two groups were comparable at various intervals from T1-6 (*P*=0.281, *P*=0.364, *P*=0.469, *P*=0.186, *P*=0.355 and 0.712 respectively). The mean arterial pressure at different points of time though higher in group A compared to group B, it was not statistically significant.

The mean dynamic compliance was found to be higher in group A as compared to group B from T3 to T6 as shown in (Figure 1) (*P*<0.001, *P*=0.010, *P*=0.003 and 0.027 respectively). The partial pressure of oxygen measured was found to be higher in group A at T2 (*P*<0.001) and at T4 (*P*<0.001) compared to group B as shown in (Figure 2). There was no statistically significant difference in $PaCo_2$ values at both intervals (*P*=0.916, *P*=0.915 respectively) as shown in (Figure 1). The mean PH value was lower in group A as compared to group B at both T2 and T4 but was not statistically significant as shown in (Table 4).

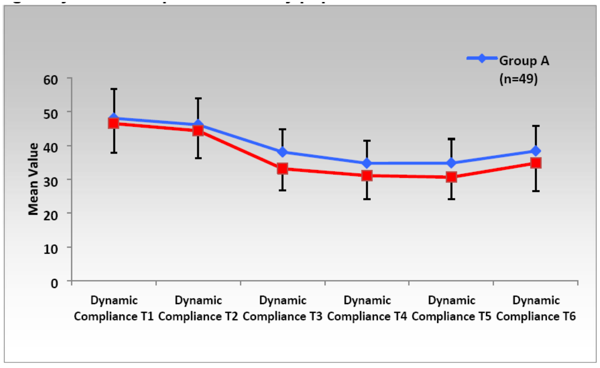

Fig 1: Dynamic compliance in study population

The dynamic complaince was higher in group A as compared with group B at all points of time intraoperatively. Statistically significant difference was noted from T3 to T6 .

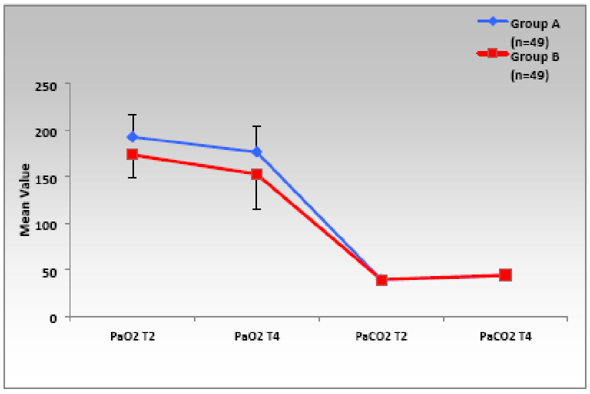

Fig. 2: PaO_2 and ($PaCO_2$) in study population at different points of time :

Table 4: PH in study population at different points of time

PH	Group A (n=49)	Group B (n=49)	*p value*
	Mean ± SD	Mean ± SD	
T2	7.42 ± 0.04	7.40 ± 0.03	0.065
T4	7.38 ± 0.04	7.37 ± 0.04	0.305

Group A: PCV, Group B: VCV, Values expressed as Mean ± SD, $p < 0.05$ considered significant, , T2: 10 min post induction, T4: 20 min post PNP

pH in study population

The pH value exhibited no statistically significant difference between the two groups at T2 (p = 0.065) and T4(p = 0.305). The mean pH value was lower in group A as compared to group B at both T2 and T4.

DISCUSSION

Although several studies have been performed to determine the optimal ventilatory settings in patients undergoing laparoscopic cholecystectomy, the answer is yet to be found. The present trial evaluated and compared PCV and VCV in laparoscopic cholecystectomy in non-obese patients with a PEEP of 7. The role of PCV for limiting the increase in airway pressure during laparoscopy is not well established. The use of VCV is common, it creates a progressive increase of airway pressure towards the peak inspiratory pressure as the full tidal volume is delivered. There is increased risk of barotrauma and uneven distribution of pulmonary gas because of high inspiratory pressures[5].

Pressure-controlled ventilation (PCV) uses a decelerating flow pattern, with the maximal flow at the beginning of inspiration until the set pressure is reached. After that the flow rapidly decreases, balancing the decreasing compliance of the expanding lung[12].This pattern results in a more homogeneous distribution of the tidal volume, improving static and dynamic compliance because of recruitment of poorly ventilated lung regions. It also leads to improvement of dead space ventilation. However, the tidal volumes during PCV are highly variable and may fall precipitously with changes in lung compliance[13]. These characteristics of PCV (faster tidal volume delivery, different gas distribution, high and decelerating inspiratory flow) tend to compensate for any potential reduction in ventilation caused by pressure limitation[14].

Oxygenation is regulated by the Fio_2 and the mean airway pressure. The mean airway pressure is determined by the peak inflating pressure (PIP), PEEP and the inspiratory time. Increasing the mean airway pressure by manipulating any of the three mentioned variables recruit alveoli, improves ventilation perfusion matching and decreases intrapulmonary shunting. Increasing the mean airway pressure may also result in significant improvement in respiratory compliance[15]. The PaO_2 in our study was statistically higher at T2 and T4 (P<0.001, P<0.001 respectively) in the PCV group compared to VCV group.

In our study the benefit of PCV in improving the pulmonary mechanics was evident during laparoscopic cholecystectomy with as well as without pneumoperitoneum. The peak pressure (Ppeak) was significantly lower in patients ventilated with PCV compared to VCV after pneumoperitoneum from T3 to T6 with *P value*s of (P<0.001, P<0.001, P<0.001 and P<0.001 respectively). The mean airway pressures were significantly higher in PCV group compared to VCV at various intervals fromT3 to T6 with *P value*s of (P<0.001, P<0.001,P<0.00 and P<0.001 respectively). The dynamic compliance was significantly higher in PCV group from T3 to T6 with *P value*s i.e P<0.001, P=0.01, P=0.003 and P=0.027 respectively. The oxygenation as measured by PaO_2 was significantly higher in PCV both before the creation of pneumoperitoneum at T2 (P<0.001) as well as at T4 (20minutes post pneumoperitoneum with p=0.001).

In a comparative study done by Gupta *et al* between VCV and PCV in obese patients undergoing laparoscopic cholecystectomy it was observed that statistically significant higher tidal volume and minute ventilation were required for maintenance of normocarbia during VCV compared with PCV. Large tidal volumes in VCV mainly ventilates the non-dependent portion of the lung, leading to excessive stretching of those regions without improving the overall ventilation. In PCV, recruitment of collapsed alveoli due to high flow rate in the early inspiratory phase leads to improved lung ventilation. In PCV adequate $C0_2$ elimination was achieved due to overall improvement in lung ventilation, inspite of low tidal volume and minute ventilation. The rise in peak pressure, plateau pressure, volutrauma, inflammatory lung injury could be avoided in PCV[16].

The respiratory mechanics and systemic stress response during laparoscopic cholecystectomy was compared and evaluated between PCV and VCV by Sen *et al* [17]. They observed higher peak pressure both before and after pneumoperitoneum in patients with VCV mode, PaO_2 values were higher in PCV mode. They suggested that when compared to VCV mode, PCV mode may improve compliance during pneumoperitoneum, improve oxygenation and reduce stress response which may be more appropriate in patients undergoing laparoscopic surgery.

The improved oxygenation in the PCV mode may be attributed to ventilation with a higher flow rate and square wave pressure. The fast alveoli with a short time constant may be overinflated at the start of the inspiration, but the subsequent homogenisation of the tidal volume spread in the alveoli prevents the incidence of the development of atelectasis. Despite the lowering of the inspiratory flow rate during the plateau pressure phase, the flow never reaches zero as in the VCV. The better oxygenation may be related to these properties of the PCV[18]. Blalick- Weber *et al* [14] in a cross over study with echocardiographic assessment evaluated the respiratory and hemodyanamics effects of VCV and PCV in patients undergoing laparoscopic urological procedures and found fall in the peak pressure values and increase in dynamic compliance with passage from VCV to PCV mode. No difference in arterial oxygenation was noted in their study.

Dynamic compliance was significantly higher in PCV in our study after creation of pneumoperitoneum. This finding is in agreement with the study of Ogurlu *et al* [19] who compared the effects of conventional VCV with the alternative mode, PCV on respiratory mechanics and non-invasive hemodynamic parameters in patients undergoing laparoscopic gynaecologic surgery and observed lower peak airway pressure, plateau pressure, airway resistance and higher compliance with PCV in laparoscopic surgery.

Halliloglu *et al*[20] found better post-operative pulmonary function in patients ventilated with a tidal volume of 6ml/kg and 8 cmH_2o PEEP than patients ventilated with a tidal volume of 10ml/kg and no PEEP. A previous trial published in LANCET 2014[21] showed that a high level of PEEP [12cmH_20] does not protect against postoperative pulmonary complications, and is more likely to cause hemodynamic depression. In our study a PEEP of 7cmH_20 was used in both the groups while comparing the effects of PCV and VCV on respiratory mechanics and oxygenation in patients undergoing laparoscopic cholecystectomy. Our study showed that PCV offers several advantages in terms of respiratory mechanics and oxygenation in patients undergoing laparoscopic cholecystectomy.

CONCLUSION

During laparoscopic cholecystectomy in non-obese patients use of PCV maintains better pulmonary mechanics as reflected by significantly lower Ppeak, higher *P* mean and higher dynamic compliance as compared to VCV. The oxygenation as measured by PaO_2 is better in PCV mode. The change in airway pressure with PCV did not result in any significant changes in the hemodyanmics.

CONFLICT OF INTERESTS

There are no conflicts of interest.

REFERENCES

1. Bablekos GD. Effects of laparoscopic cholecystectomy on lung function: A systematic review. World J Gastroenterol 2014;20(46):17603.
2. Joris J. Anesthesia for laparoscopic surgery. In: Miller RD, editor. Miller's Anesthesia. Philadelphia: Elsevier, Churchill Livingstone; 2005. p. 2285–306.
3. Gutt CN, Oniu T, Mehrabi A, Schemmer P, Kashfi A, Kraus T, *et al*. Circulatory and Respiratory Complications of Carbon Dioxide Insufflation. Dig Surg 2004;21(2):95–105.
4. Safran DB, Orlando R. Physiologic effects of pneumoperitoneum. Am J Surg 1994;167(2):281–6.
5. Lin F, Pan L, Qian W, Ge W, Dai H, Liang Y. Comparison of three ventilatory modes during one-lung ventilation in elderly patients. Int J Clin Exp Med 2015;8(6):9955–60.
6. Lohser J. Evidence-based management of one-lung ventilation. Anesthesiology Clin. 2008;26(2):241–72.
7. Ciftci B, Aksoy M, Ince I, Ahıskalıoglu A, Yılmazel Ucar E. The Effects of Positive End-Expiratory Pressure at Different Levels on Postoperative Respiration Parameters in Patients Undergoing Laparoscopic Cholecystectomy. J Invest Surg 2018;31(2):114–20.
8. Kim JY, Shin CS, Kim HS, Jung WS, Kwak HJ. Positive end-expiratory pressure in pressure-controlled ventilation improves ventilatory and oxygenation parameters during laparoscopic cholecystectomy. Surg Endosc 2010; 24(5):1099–103.
9. Kundra P, Subramani Y, Ravishankar M, Sistla SC, Nagappa M, Sivashanmugam T. Cardiorespiratory effects of balancing PEEP with intra-abdominal pressures during laparoscopic cholecystectomy: Surg Laparosc Endosc Percutan Tech 2014;24(3):232–9.
10. Sen O, Erdogan Doventas Y. Effects of different levels of end-expiratory pressure on hemodynamic, respiratory mechanics and systemic stress response during laparoscopic cholecystectomy. Braz J Anesthesiol Engl Ed 2017;67(1):28–34.
11. Lee HJ, Kim KS, Jeong JS, Shim JC, Cho ES. Optimal positive end-expiratory pressure during robot-assisted laparoscopic radical prostatectomy. Korean J Anesthesiol 2013;65(3):244.
12. Cadi P, Guenoun T, Journois D, Chevallier J-M, Diehl J-L, Safran D. Pressurecontrolled ventilation improves oxygenation during laparoscopic obesity surgery compared with volume-controlled ventilation. Br J Anaesth 2008;100(5):709–16.
13. Lohser J. Evidence-based management of one-lung ventilation. Anesthesiology Clin. 2008;26(2):241–72.
14. Balick-Weber C-C, Nicolas P, Hedreville-Montout M, Blanchet P, Stéphan F. Respiratory and haemodynamic effects of volume-controlled vs pressurecontrolled ventilation during laparoscopy: a cross-over study with echocardiographic assessment. Br J Anaesth. 2007;99(3):429–35.
15. Tobias JD. Conventional mechanical ventilation. Saudi J Anaesth 2010;4(2):86–98.
16. Gupta SD, Kundu SB, Ghose T, Maji S, Mitra 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(3):276.
17. Sen O, Umutoglu T, Aydın N, Toptas M, Tutuncu AC, Bakan M. Effects of pressure-controlled and volume-controlled ventilation on respiratory mechanics and systemic stress response during laparoscopic cholecystectomy. SpringerPlus [Internet] 2016;5. Available from: https:// www. ncbi. nlm. nih. gov/ pmc/ articles/PMC4783310/

18. Shehri AMA, El-Tahan MR, Metwally RA, Qutub H, Ghoneimy YFE, 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(4):880–4.

19. Oğurlu M, Küçük M, Bilgin F, Sizlan A, Yanarateş O, Eksert S, *et al*. Pressurecontrolled vs volume-controlled ventilation during laparoscopic gynecologic surgery. J Minim Invasive Gynecol 2010;17(3):295–300.

20. Haliloglu M, Bilgili B, Ozdemir M, Umuroglu T, Bakan N. Low Tidal Volume Positive End-Expiratory Pressure versus High Tidal Volume Zero-Positive EndExpiratory Pressure and Postoperative Pulmonary Functions in Robot-Assisted Laparoscopic Radical Prostatectomy. Med Princ Pract Int J Kuwait Univ Health Sci Cent 2017;26(6):573–8.

21. PROVE Network Investigators for the Clinical Trial Network of the European Society of Anaesthesiology, Hemmes SNT, Gama de Abreu M, Pelosi P, Schultz MJ. High versus low positive end-expiratory pressure during general anaesthesia for open abdominal surgery (PROVHILO trial): a multicentre randomised controlled trial. Lancet Lond Engl 2014;384(9942):495–503.