The Effect of Different Levels of Positive End Expiratory Pressure on Oxygenation and Hemodynamics During Laparoscopic Cholecystectomy in Obese Patients

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ABSTRACT
Background: Obesity represents a major health problem. There are multiple strategies to reduce perioperative respiratory complications, and one of these strategies is the use of intraoperative recruitment maneuvers (RM), with the addition of positive end expiratory pressure (PEEP).
Objectives: This study was aimed to compare the effect of using different levels of positive end expiratory pressure on oxygenation and hemodynamics and to determine the optimal PEEP level that provide the maximum beneficial effect on oxygenation with minimal effect on hemodynamics during laparoscopic cholecystectomy in obese patients.
Patients and Methods: This study was carried out at Zagazig University Hospitals where fifty-six male and female patients scheduled for laparoscopic cholecystectomy aged from 21 to 60 years, ASA physical status grade II and body mass index (BMI) 30-34 kg/m^2. Patients were classified into four groups (14 each), underwent history taking, general examination, and laboratory investigations. **Results**: Regarding changes in heart rate and mean arterial pressure (MAP) at different intervals within and between the four studied groups, there was statistically significant difference between the four groups regarding heart rate and MAP after induction Ti, T1 (20 min), T2 (40 min) and T3 (60 min) with the least reported heart rate and MAP was significantly found in group 9 (PEEP9) in relation to the other groups.
Conclusions: It could be concluded that PEEP 7 H_2O is the optimal PEEP level with maximum beneficial effect on oxygenation without affecting hemodynamics during laparoscopic cholecystectomy in obese patients.
Keywords: PEEP, EELV, Laparoscopic, Obese, FRC.

INTRODUCTION
World Health Organization (WHO) defined obesity as a Body Mass Index (BMI) above 30 kg/m^2. The characteristic physiological changes induced by obesity such as decreased Functional Residual Capacity (FRC), increased demand for oxygen, decreased lung compliance, and altered ventilation perfusion ratio make these patients prone to perioperative complications like atelectasis, hypoxia and hypercapnia [(1)]. The decrease in FRC can lead to ventilation at low lung volume, which in turn can lead to peripheral airway collapse, when the airways closing volume exceeds the end-expiratory lung volume (EELV) [(2)]. Postoperative lung atelectasis develops with both intravenous (IV) and inhaled anesthesia and whether the patient is breathing spontaneously or is paralyzed and ventilated mechanically [(3)]. The adverse effects of atelectasis persist into the postoperative period and can affect patient recovery [(4)].

Laparoscopic surgery is usually performed by intraabdominal insufflation of carbon dioxide; this insufflation leads to an increase in intraabdominal pressure. The increase in intraabdominal pressure could induce shift of the diaphragm cranially and compression of basal lung regions. Thus, the increase in intraabdominal pressure could accentuate the effects of atelectasis already predisposed to by general anesthesia, and therefore laparoscopic surgeries are associated with a frequent incidence of lung atelectasis [(5)]. During general anesthesia, as well as during the immediate postoperative period, obese patients are more likely than nonobese patients to develop atelectasis that resolves more slowly [(6)]. This is because of a marked impairment of the respiratory mechanics promoting airway closure with reduction of the oxygenation index (Pao2/PAo2) to a greater extent than in healthy-weight subjects [(3)].

There are different intra-operative ventilation strategies in these patients to re-inflate the collapsed lungs and optimize the oxygenation. These strategies include the application of Positive End Expiratory Pressure (PEEP) or Recruitment Maneuvers (RM) in the form of application of positive airway pressure to re-inflate the collapsed lung tissue [(7)]. Positive end-expiratory pressure (PEEP) can counterbalance the decrease in EELV, thereby preventing atelectasis during the intraoperative period, improving pulmonary mechanics and decreasing pulmonary shunt [(8)].

In the present study, we have aimed to compare the effect of using different levels of positive end-expiratory pressure on oxygenation and hemodynamics and to determine the optimal PEEP level that provide the maximum beneficial effect on oxygenation with minimal effect on hemodynamics during laparoscopic cholecystectomy in obese patients.

PATIENTS AND METHODS
This prospective randomized comparative clinical trial included a total of 56 male and female patients scheduled for laparoscopic cholecystectomy, attending at anesthesia, surgical intensive care and pain

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medicine, Zagazig University Hospitals. This study was conducted between June 2018 to December 2020.

Inclusion criteria: Patients with the following criteria: age between 21-60 years old, both sex; male and female, ASA II, BMI 30-34 kg/m^2, and duration of surgery not more than 2 hours.

Exclusion criteria: Patients with pulmonary disease, heart disease, uncontrolled hypertension, renal failure, and pregnancy or any other cause of increase intra-abdominal pressure e.g ascites.

Subjects and Grouping: The study included a total number of 56 subjects. Studied subjects were divided randomly into four equal groups: Group zero (ZEEP): 14 Patients, no PEEP was used, group 5 (PEEP5): 14 Patients, 5 cm H_2O PEEP was used, group 7 (PEEP7): 14 Patients, 7 cm H_2O PEEP was used, group 9 (PEEP9): 14 Patients, 9 cm H_2O PEEP was used.

***Ethical Consideration*:**

An approval of the study was obtained from Zagazig University Academic and Ethical Committee. Every patient signed an informed written consent for acceptance of the operation. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

Statistical Analysis

All data were collected, tabulated and statistically analyzed using SPSS 20.0 for windows (SPSS Inc., Chicago, IL, USA). Quantitative data were expressed as the mean ± SD and qualitative data were expressed as absolute frequencies (number) & relative frequencies (percentage). One way ANOVA test was used to compare between more than two independent groups of non-normally distributed variables with post hoc test to explore significant between groups. Repeated measurement ANOVA was used to compare measures of different intervals within the same group. Percent of categorical variables were compared using Chi-square test. All tests were two sided. p-value < 0.05 was considered statistically significant (S), p-value ≥ 0.05 was considered statistically insignificant (NS).

RESULTS

There was no significant difference between the studied groups regarding patients' data and duration of surgery (table 1).

Table (1): Patients' data and duration of surgery in the four studied groups:

Variable	Group (0) (ZEEP) (n=14)	Group (5) (PEEP 5) (n=14)	Group (7) (PEEP 7) (n=14)	Group (9) (PEEP 9) (n=14)	Tests	
					f/x2	P value
Age (years)	38.15±4.94	36.46±6.05	40.15±4.63	37±8.21	0.926	0.435
Weight (kg)	93.38±4.23	94.07±5.05	93.53±3.20	92.30±5.03	0.361	0.781
Height (cm)	167.15±4.76	166.84±1.67	168±2.71	167.6±3.5	0.787	0.507
BMI (kg/m2)	33.43±0.78	33.03±1.12	33.6±0.60	32.7±1.12	2.315	0.088
Sex						
Male **Female**	6 (42.8%) 8 (57.2%)	5 (35.7%) 9 (64.3%)	6 (42.8%) 8 (57.2%)	4 (28.6%) 10 (72.4%)	0.923	0.494
Duration of surgery (min)	98.46±16.25	104.23±14.41	98.46±14.34	102.3±12.18	0.524	0.668

f = one-way ANOVA test was used for analysis of means. X^2 = Chi square test was used for analysis of numbers.

As shown in table (2) there were no statistically significant differences between the studied groups regarding the baseline values or at the end of the surgery. There were statistically significant difference between the four studied groups regarding heart rate after induction Ti, T1 (20 min), T2 (40 min) and T3 (60 min).

Table (2): Changes in heart rate at different intervals within and between the four studied groups:

Heart rate (beat/min):		Group 0 (ZEEP) (n=14)	Group 5 (PEEP 5) (n=14)	Group 7 (PEEP 7) (n=14)	Group 9 (PEEP 9) (n=14)	P value
		(Mean±SD)	(Mean±SD)	(Mean±SD)	(Mean±SD)	
(T0) Base line value		102.0±6.65	103.6±5.77	103.07±3.99	99.5±7.54	0.346
(Ti) Just after induction		99.77±7.07	97.69±5.54	100±3.81	81.69±11.82	**0.000****
T1 (20 minutes after induction)		100.92±7.26	102±5.58	99.84±6.5	79.15±15.51	**0.000****
T2 (40 minutes after induction)		100.46±7.71	102.92±7.67	99±5.08	79.0±18.32	**0.000****
T3 (60 minutes after induction)		100.84±6.57	102.38±6.18	99±4.47	78.76±16.35	**0.000****
T4 (end of surgery)		100.0±6.38	99.61±8.19	99.92±3.84	98.07±8.77	0.888
T5 (20 minutes after extubation)		100.2±6.12	99.77±8.19	99.62±3.34	98.27±8.57	0.868
Repeated measurement ANOVA test	**F**	**32.9**	**18.55**	**18.5**	**56.12**	**-----------------**
	P-value	**0.004***	**0.194**	**0.195**	**<0.001****	**-**

As shown in table (3), there was no statistically significant differences between the studied groups regarding the baseline values. There was statistically significant difference between the four studied groups regarding MAP after induction Ti, T1 (20 min), T2 (40 min) and T3 (60 min) and T4 with the least reported MAP (hypotension) was significantly found in group 9 (PEEP9) in relation to the other groups.

Table (3): Changes in mean Arterial pressure (MAP) changes at different intervals within and between the four studied groups:

MAP (mm Hg):	**Group 0 (ZEEP) (n=14)**	**Group 5 (PEEP 5) (n=14)**	**Group 7 (PEEP 7) (n=14)**	**Group 9 (PEEP 9) (n=14)**	**P value**
	(Mean±SD)	**(Mean±SD)**	**(Mean±SD)**	**(Mean±SD)**	
(T0) Base line value	101.77±2.09	99.62±2.22	100.29±2.32	99.77±2.35	0.060
(Ti) Just after induction	98.54±2.26	82.31±4.82	82.08±4.77	83.84±3.61	**0.000****
T1 (20 minutes after induction)	97.46±1.71	79.46±5.51	78.92±5.85	71.30±4.38	**0.000****
T2 (40 minutes after induction)	96.61±3.75	79.38±4.59	77.38±4.33	67.61±4.01	**0.000****
T3 (60 minutes after induction)	98.61±4.53	81±4.52	74.23±3.03	67.07±4.27	**0.000****
T4 (end of surgery)	101.92±4.77	84.69±2.81	81.53±3.43	70.69±4.44	**0.000****
T5 (20 minutes after extubation)	101.72±4.37	84.73±2.77	81.25±3.33	71.1±4.34	**<0.000****
Repeated measurement ANOVA test: F	**22.7**	**37.7**	**38.9**	**28.7**	
Repeated measurement ANOVA test: P value	**0.07***	**0.001***	**0.001***	**0.013***	

f = one-way ANOVA test was used for analysis of means.

As shown in table (4), although there no statistically significant differences between the studied groups regarding SPO_2 at the different intervals baseline T0, Ti, T1 (20 min), T2 (40 min), T3 (60 min), T4 and T5 but it was noticed that the levels of oxygen were higher in group 7 (PEEP7) and group 9 (PEEP9). There was statistically significant increase of the Spo2 within the four studied groups at the different intervals.

Table (4): Changes in Oxygen saturation (SPO_2) at different intervals within and between the four studied groups:

SPO2	**Group 0 (ZEEP) (n=14)**	**Group 5 (PEEP 5) (n=14)**	**Group 7 (PEEP 7) (n=14)**	**Group 9 (PEEP 9) (n=14)**	**P value**
	(Mean±SD)	**(Mean±SD)**	**(Mean±SD)**	**(Mean±SD)**	
(T0) Base line value	98.15±0.898	98.15±0.987	98.31±0.751	98.23±0.725	0.961
(Ti) Just after induction	98.77±0.438	98.77±0.832	99.23±0.599	99.38±0.51	0.023
T1 (20 minutes after induction)	99±0.000	99.30±0.48	99.30±0.48	99±0.577	0.117
T2 (40 minutes after induction)	98.85±0.375	99.23±0.599	99.31±0.48	99.38±0.650	0.065
T3 (60 minutes after induction)	99.08±0.277	99.15±0.376	99.23±0.439	99.31±0.480	0.500
T4 (end of surgery)	99.28±0.506	99.23±0.438	99.38±0.650	99.38±0.506	0.845
T5 (20 minutes after extubation)	99.38±0.506	99.25±0.44	99.58±0.640	99.44±0.6	0.845
Repeated measurement ANOVA test: F	**41.3**	**41.09**	**32.4**	**27.04**	
Repeated measurement ANOVA test: P value	**0.001***	**0.001***	**0.004***	**0.02***	

As shown in table (5), although there were no statistically significant differences between the studied groups regarding End tidal $ETCO_2$ at the different intervals baselineT0, Ti, T1 (20 min), T2 (40 min), T3 (60 min), T4 and T5 but it was noticed that the levels of end tidal CO_2 were lower in group 7 (PEEP7) and group 9 (PEEP9). There were statistically significant decrease of the end tidal CO_2 within the four studied groups at the different intervals.

Table (5): Changes in end tidal carbon dioxide tension ($ETCO_2$) at different intervals within and between the four studied groups:

ETCO2		Group 0 (ZEEP) (n=14)	Group 5 (PEEP 5) (n=14)	Group 7 (PEEP 7) (n=14)	Group 9 (PEEP 9) (n=14)	P value
		(Mean±SD)	**(Mean±SD)**	**(Mean±SD)**	**(Mean±SD)**	
(T0) Base line value		31.85±2.823	33.69±1.702	33.46±2.18	33.61±1.61	0.101
(Ti) Just after induction		29.54±1.94	29.55±2.96	29.07±2.397	28.84±1.67	0.857
T 1 (20 minutes after induction)		29.54±1.61	29.92±2.29	29.8±2.39	28.84±1.67	0.421
T2 (40 minutes after induction)		29.85±2.64	30.0±1.68	29.08±2.46	27.07±1.55	**0.004***
T3 (60 minutes after induction)		28.15±2.07	28.69±1.11	28.08±1.11	26.46±2.11	**0.048***
T4 (end of surgery)		28.1±2.0	28.71±1.2	28.1±1.3	26.5±2.2	**0.04***
Repeated measurement ANOVA test	***F***	**59.83**	**40.5**	**24.2**	**19.34**	
	***P* value**	**0.001***	**0.001***	**0.004***	**0.02***	

As shown in table (6), there were no statistically significant differences between the studied groups regarding the baseline values. There were statistically significant difference between the four studied groups regarding PaO2after induction Ti, T1 (20 min), T2 (40 min), T3 (60 min), T4 and T5 with the higher reported PaO2 levels were significantly found in group 7 (PEEP7) and group 9 (PEEP9) in relation to the other groups.

Table (6): Changes in partial pressure of arterial oxygen tension (PaO_2) at different intervals within and between the four studied groups:

PaO2		Group 0 (ZEEP) (n=14)	Group 5 (PEEP 5) (n=14)	Group 7 (PEEP 7) (n=14)	Group 9 (PEEP 9) (n=14)	**P value**
		(Mean±SD)	**(Mean±SD)**	**(Mean±SD)**	**(Mean±SD)**	
(T0) Base line value		85.07±1.49	84.46±1.56	84.23±1.64	84.08±1.25	0.349
(Ti) Just after induction		200±39.52	262.92±74.11	290.07±38.19	358.31±48.32	**0.000****
T1 (20 minutes after induction)		209.69±28.63	281.76±67.17	307.46±39.43	367.53±31.698	**0.000****
T2 (40 minutes after induction)		217.84±22.49	290.07±66.04	322.53±33.72	373.53±31.28	**0.000****
T3 (60 minutes after induction)		220.61±22.32	295.69±65.54	336.92±16.71	377.77±27.18	**0.000****
T4 (end of surgery)		149.38±7.76	152±6.89	154±7.76	156.84±1.67	**0.024***
T5 (20 minutes after extubation)		148.35±7.76	152.4±6.99	154.3±7.66	156.74±1.72	**0.021***
Repeated measurement ANOVA test	***F***	**135.7**	**116.7**	**135.4**	**96.8**	
	***P* value**	**<0.001****	**<0.001****	**<0.001****	**<0.001****	

As shown in table (7), there were no statistically significant differences between the group 7 and group 9 regarding P/F ratio changes at different intervals but there were statistically significant differences between group0 and group 5 in relation to group 7 and group 9 at the different intervals with groups 7 and 9 had significantly higher levels of P/F ratio.

Table (7): Changes in ratio of arterial oxygen partial pressure to inspiratory oxygen concentration (P/F ratio) at different intervals within and between the four studied groups:

P /F ratio		Group 0 (ZEEP) (n=14) (Mean±SD)	Group 5 (PEEP 5) (n=14) (Mean±SD)	Group 7 (PEEP 7) (n=14) (Mean±SD)	Group 9 (PEEP 9) (n=14) (Mean±SD)	P value
(T0) Base line value	394.79±6.62		397.18±5.24	401±7.96	403.29±5.28	0.006*
(Ti) Just after induction	200±39.52		276.07±61.44	377.53±5.19	331.23±59.07	0.000**
T 1 (20 minutes after induction)	209.69±28.63		295.92±59.80	380.15±20.37	346±38.42	0.000**
T2 (40 minutes after induction)	217.84±22.49		319.76±49.46	385.85±7.37	351.61±37.93	0.000**
T3 (60 minutes after induction)	220.61±22.32		324.15±44.48	388.31±9.03	359.23±33.14	0.000**
T4 (end of surgery)	450.64±7.67		490.03±5.22	473.3±21.10	477.39±22.89	0.000**
T5 (20 minutes after extubation)	451.54±7.55		490.23±5.12	473.34±21.3	477.4±22.79	0.000**
Repeated measurement ANOVA test	*F*	117.2	113.4	49.4	115.7	
	P value	<0.001**	<0.001**	<0.001**	<0.001**	

DISCUSSION

For changes in heart rate at different intervals within and between the four studied groups in the current study, there was no statistically significant differences between the studied groups regarding the baseline values or at the end of the surgery. There was statistically significant differences between the four studied groups regarding heart rate after induction Ti, T1 (20 min), T2 (40 min) and T3 (60 min).

This decrease in heart rate in the current study might be explained by parasympathetic predominance caused by vagal stimulation due to over stretch of the peritoneum as the patients in the present study were affected by three factors: (1) Pneumoperitoneum: Increased intra-abdominal pressure during pneumoperitoneum triggers several pathophysiological mechanisms independently of the type of used gas, bradyarrhythmias (sinus bradycardia, nodal rhythm, atrio ventricular dissociation and asystole) which are due to a vagal-mediated cardiovascular reflex initiated by stretching of the peritoneum during peritoneal insufflations [9], (2) Obese patient has already high intraabdominal pressure as increased BMI correlates with increased intraabdominal pressure [10], (3) PEEP effect: the intraabdominal pressure (IAP) increased with the increase in PEEP values, and caused mild intraabdominal hypertension (IAH) [11]. These factors cause more and more stretch of the peritoneum and stimulation of vagal tone and more decrease in heart rate especially with high PEEP.

The decrease in heart rate in the current study was gradual and accepted in group 0 (ZEEP) <group 5<group 7 but was more profound bradycardia and atropine was needed in group 9. Thereby, application of PEEP 7cmH_2O was considered safer regarding its effect on heart rate.

The results of the present study were in agreement with **Bluth *et al.*** [12]. who compared effect of intraoperative high PEEP with recruitment maneuvers vs low PEEP on postoperative pulmonary complications in obese patients in which patients were randomized to the high level of PEEP group, consisting of a PEEP level of 12 cmH2O with alveolar recruitment maneuvers (a stepwise increase of tidal volume and eventually PEEP) or to the low level of PEEP group, consisting of a PEEP level of 4 cmH2O. All patients received volume-controlled ventilation with a tidal volume of 7 mL/kg of predicted body weight and found that intraoperative bradycardia was more frequent in patients randomized to higher levels of PEEP.

Regarding changes in mean arterial pressure (MAP) at different intervals within and between the four studied groups in the current study there was no statistically significant differences between the studied groups regarding the baseline values. There were statistically significant differences between the four studied groups regarding MAP after induction Ti, T1(20 min), T2 (40 min) and T3 (60 min) and T4.

These results were in agreement with the study of **Bluth *et al.*** [12] who compared effect of intraoperative high PEEP with recruitment maneuvers versus low PEEP on postoperative pulmonary complications in obese patients in which patients were randomized to the high level of PEEP group, consisting of a PEEP level of 12 cmH2O with alveolar recruitment maneuvers (a stepwise increase of tidal volume and eventually PEEP) or to the low level of PEEP group, consisting of a PEEP level of 4 cmH2O. All patients received volume-controlled ventilation with a tidal volume of 7 mL/kg of predicted body weight and found that intraoperative hypotension was more frequent in patients randomized to higher levels of PEEP.

The current study showed that using different levels of positive end expiratory pressure improves oxygenation during laparoscopic cholecystectomy in obese patients especially PEEP 7 and 9.

The results of the present study were in agreement with the study of **Cinnella *et al.*** [13] who studied effects of recruitment maneuver and positive end-expiratory pressure on respiratory mechanics and transpulmonary pressure during laparoscopic surgery and found positive results regarding oxygenation. In contrast to the results of this study, the study of **Dyhr *et al.*** [14] who observed that pneumoperitoneum impaired respiratory mechanics and gas exchange. These effects was due to development of atelectasis and reduced lung volumes in patients undergoing laparoscopic surgery and this results is due to that the patients in their study had higher BMI than current study.

There was no statistically significant differences between the studied groups regarding the baseline values, after induction and T2 of $PaCO_2$ although lower values were reported in groups 7 and 9. There was statistically significant difference between the studied groups regarding $PaCO_2$ at T2 (40 min) between both (PEEP0, PEEP5) and PEEP9. $PaCO_2$ at T5 was significantly lower in-group 9. There was tendency to decrease in mean value between the four studied groups regarding the $PaCO_2$.

These results were in agreement with the results of **Sen and Erdogan.** [15] who compared the effects of 5 and 10 cm H_2O PEEP levels with pneumoperitoneum on CO_2 elimination on two group of patients scheduled for laparoscopic cholecystectomy and found that $PaCO_2$ values were lower in PEEP 10 group and observed that during the pneumoperitoneum application of 10 cmH_2O PEEP enhanced CO_2 washout more than5 cmH_2O PEEP. While the results of the present study were not in agreement of the study of **Wei *et al.*** [16] as there was a significant increase of $PaCO_2$ during the emergence stage which might be because patients in that study were without repeated alveolar recruitment Maneuvers.

There was no statistically significant differences between the group 7 and group 9 regarding P/F ratio changes at different intervals but there was statistically significant differences between group 0 and group 5 in relation to group 7 and group 9 at the different intervals with groups 7 and 9 had significantly higher levels of P/F.

Our results were in agreement with the study of **Spadaro *et al.*** [17] who studied effect of positive end-expiratory pressure on pulmonary shunt and dynamic compliance during abdominal surgery and found that the level of shunt decreased and high level of P/F ratio and oxygenation improved with PEEP 10. In contrast to current study, the study of **Chalhoub *et al.*** [18] found that Arterial oxygenation parameters decreased and this might be explained by using PEEP alone unlike the present study as recruitment maneuver was used.

CONCLUSION

It could be concluded that using different levels of positive end expiratory pressure during laparoscopic cholecystectomy in obese patients improves oxygenation and prevent postoperative pulmonary complications. PEEP 7 H_2O is the optimal PEEP level with maximum beneficial effect on oxygenation without affecting hemodynamics during laparoscopic cholecystectomy in obese patients.

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REFERENCES

1. **Aldenkortt M, Lysakowski C, Elia N *et al.* (2012):** Ventilation strategies in obese patients undergoing surgery: a quantitative systematic review and meta-analysis. British Journal of Anaesthesia, 109(4): 493-502.
2. **Pelosi P, Ravagnan I, Giurati G *et al.* (1999):** Positive end-expiratory pressure improves respiratory function in obese but not in normal subjects during anesthesia and paralysis. The Journal of the American Society of Anesthesiologists, 91(5):1221-26.
3. **Talab H, Zabani I, Abdelrahman H *et al.* (2009):** Intraoperative ventilatory strategies for prevention of pulmonary atelectasis in obese patients undergoing laparoscopic bariatric surgery. Anesthesia & Analgesia, 109(5): 1511-6.
4. **Duggan M, Kavanagh B, Warltier D (2005):** Pulmonary atelectasis: a pathogenic perioperative entity. The Journal of the American Society of Anesthesiologists, 102(4):838-54.
5. **Azab T, El-Masry A, Salah M *et al.* (2005):** Effects of intraoperative use of positive end expiratory pressure on lung atelectasis during laparoscopic cholecystectomy. Egyptian Journal of Anaesthesia, 21(3):219.
6. **Eichenberger A, Proietti S, Wicky S *et al.* (2002):** Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesthesia & Analgesia, 95(6):1788-92.
7. **Elokda S, Farag H (2019):** Preemptive Alveolar Recruitment Maneuver Followed by PEEP in Obese

Patients Undergoing Laparoscopic Gastric Banding. Does it make a Difference? A Randomized Controlled Clinical Study. The Open Anesthesia Journal, 13(1): 1-4.

8. **Loring S, Behazin N, Novero A *et al.* (2014):** Respiratory mechanical effects of surgical pneumoperitoneum in humans. Journal of Applied Physiology, 117(9):1074-9.
9. **Gutt C, Oniu T, Mehrabi A (2004):** Circulatory and respiratory complications of carbon dioxide insufflation. Digestive Surgery, 21(2):95-105.
10. **Frezza E, Shebani K, Robertson J *et al.* (2007):** Morbid obesity causes chronic increase of intraabdominal pressure. Digestive Diseases and Sciences, 52(4):1038-41.
11. **Dumanlidağ U, Yuzkat N, Soyalp C (2019):** Effects of Increasing Positive End-Expiratory Pressure (PEEP) Values on Intraabdominal Pressure and Hemodynamics: A Prospective Clinical Study. Eastern Journal of Medicine, 24(2):235-41.
12. **Bluth T, Neto A, Schultz M *et al.* (2019):** Effect of intraoperative high positive end-expiratory pressure (PEEP) with recruitment maneuvers vs low PEEP on postoperative pulmonary complications in obese patients: a randomized clinical trial. Jama., 321(23):2292-305.
13. **Cinnella G, Grasso S, Spadaro S *et al.* (2013):** Effects of recruitment maneuver and positive end-expiratory pressure on respiratory mechanics and transpulmonary pressure during laparoscopic surgery. The Journal of the American Society of Anesthesiologists, 118(1):114-22.
14. **Dyhr T, Nygård E, Laursen N *et al.* (2004):** Both lung recruitment maneuver and PEEP are needed to increase oxygenation and lung volume after cardiac surgery. Acta Anaesthesiologica Scandinavica, 48(2):187-97.
15. **Sen O, Erdogan Doventas Y (2017):** Effects of different levels of end expiratory pressure on hemodynamic, respiratory mechanics and systemic stress response during laparoscopic cholecystectomy. Revista Brasileira de Anestesiologia, 67:28-34.
16. **Wei K, Min S, Cao J *et al.* (2017):** Repeated alveolar recruitment maneuvers with and without positive end-expiratory pressure during bariatric surgery: a randomized trial. Minerva Anestesiologica, 84(4):463-72.
17. **Spadaro S, Karbing D, Mauri T *et al.* (2016):** Effect of positive end-expiratory pressure on pulmonary shunt and dynamic compliance during abdominal surgery. British Journal of Anaesthesia, 116(6):855-61.
18. **Chalhoub V, Yazigi A, Sleilaty G *et al.* (2007):** Effect of vital capacity manoeuvres on arterial oxygenation in morbidly obese patients undergoing open bariatric surgery. European Journal of Anaesthesiology, 24 (3): 283-8.