Original Research Article

Comparison of the effect of positive end expiratory pressure on respiratory mechanics and arterial oxygenation in laproscopic cholecystectomy

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Abstract

Objective: To study and compare the effects of PEEP on Respiratory Mechanics, Oxygenation Index and Heamodynamic changes at different intervals. **Methods** :This prospective study was done to evaluate the effects of extrinsic PEEP on respiratory mechanics, haemodynamics and arterial blood gases during laproscopic cholecystectomy in obese patients. **Results:** Primary outcome variable was ratio of arterial oxygen partial pressure to inspiratory oxygen concentration Pa02/Fi02 and other variables related to gas exchange, oxygenation, ventilation, respiratory mechanics and haemodynamics were reported separately for patients randomized to PEEP application as well as control group. All continuous data are expressed as mean ± SD. Comparison of two groups were done by using student's test. **Conclusion**PEEP improves oxygenation in morbidly obese patients without causing hemodynamic instability. This improved oxygenation persists throughout the surgery but it promptly dissipates after tracheal extubation.

Keywords:Positive End Expiratory Pressure ,Respiratory Mechanics ,Arterial Oxygenation , Laproscopic Cholecystectomy.

Introduction

One of the factors contributing to development of modern anaesthesia is early outcome and return to work as early as possible. The anaesthetic drugs, complicated surgical procedures and the patient's condition due to existing medical disease increases the risk. Laproscopic surgery has increased in popularity and extends not only to gynecological procedure but also to various abdominal surgeries like gall bladder disease and diagnostic procedures within abdomen. It offers several benefit over open procedure like smaller incision, decreased post operative pain, early ambulation, minimal post operative scar & early return to work but at the same time insufflating gas into peritoneal cavity (pneumoperitonium) creates lots of problem and consideration to anaesthesiologist in relation to cardio vascular and respiratory function. Upper abdominal surgery performed through a subcostal or midline incision is associated with significant reduction in functional residual and vital capacity that can lead to atelectasis and hypoxemia.[1-3]

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There are also marked alterations in breathing patterns. It has been demonstrated that contribution of abdominal compartment to tidal volume decreased after open cholecystectomy. Laproscopic cholecystectomy allows removal of gall bladder without a subcostal or midline incision. Laproscopic cholecystectomy has gained worldwide acceptance because of shortened hospital stays and improved patient satisfaction[4] This surgical laproscopic procedure involves changes in patient position from supine to reverse trendelenburg and requires intra peritoneal CO_2 insufflation. The induction and maintainence of peritoneal insufflation by CO_2 at a constant rate could result in several adverse haemodynamic and respiratory effects. Laproscopic cholecystectomy may require longer periods of peritoneal insufflation than previously reported in gynecological procedure. It is conceivable that longer CO_2 insufflation might impede diaphragmatic movement and increase the CO_2 load for ventilation. Insufflation causes intraabdominal distension resulting in increased peak inspiratory pressure and pulmonary resistance and decrease in compliance of respiratory system[5] CO_2 absorbed from peritoneal cavity results in hypercapnia, which further modify respiratory mechanics. These changes may be deleterious to patients with compromised ventilatory function. Therefore respiratory mechanisms, blood gases and haemodynamics must be monitored to identify mechanical and ventilatory effects of insufflation. Under anasthesia closing volume exceed their FRC causing airway closure and resulting in increased alveolar arterial difference in oxygen tension and more so ever in laproscopic cholecysteclomy there is further reduction of FRC due to upward replacement of diaphragm by CO_2 insufflation intraperitonealy further compromises lung complaince resulting in closure of airways. This will result in arterial hypoxemia hypercarbia, acidosis & hyperdynamic circulation in respiratory mechanism including increase in total respiratory lung and chest wall elastance and lung resistance. Closure of airways causing collapse is more in obese patients as they have lower lung volume, greater elastance and lower inflection point.Under anaesthesia morbidly obese patients closing volume can exceed their functional residual capacity causing airway closure and resulting in increased alveolar arterial difference in oxygen tension. There are various method of recruitments to improve oxygenation & lung compliance during anesthesia specially in laproscopic surgery, first is by increasing minute ventilation either by increasing respiratory rate or providing large tidal volume. Another way to improve oxygenation is by applying PEEP.PEEP prevents alveoli from collapsing and may reopen collapsed lung segments thereby improving gas exchange by decieasing intrapulmonary shunting and when appropriately applied increases pulmonary compliance. Because of beneficial effects of PEEP on pulmonary physiology and gas exchange, we undertook this study of evaluating effects of extrinsic PEEP on respiratory mechanics, arterial blood gases and haemodynamics on patients undergoing laproscopic cholecystectomy[9]

Materials and methods

This prospective study was done to evaluate the effects of extrinsic PEEP on respiratory mechanics, haemodynamics and arterial blood gases during laproscopic cholecystectomy in obese patients.

Methodology

After ethics committee approval, we conducted prospective randomized study to quantify effect of PEEP on Pa02 duding laproscopic cholecystectomy. We recruited obese patients ASA 1 and 2 of age between 30-50yrs and BMI>40kg/m^2. None of patients had significant preoperative pulmonary disease (forced expiratory volume in one second < 50 % of predicted) or active asthma.

Consent

Written consent was obtained from the relatives of patients after explaining them the nature and purpose of the study. They were assured that confidentiality would be strictly maintained. The option to withdraw from the study was always open .All patients in the study gave informed consent and were fully explained the purpose and procedure to be followed. A through systemic and general examination of patients was done. All the routine investigations, total and differential leucocyte counts, blood sugar, blood urea, routine microscopic examination of urine, ECG, X ray chest were done in all the patients. Randomization of patients was done with closed chit method into 2 groups: Group I- Controlled mechanical ventilation Group II- Controlled mechanical ventilation with 5cm of water of Extrinsic PEEP[10-12]

Exclusion criteria

Patients with uncontrolled hypertension, heart block, pulmonary disease like COPD or Bronchial asthma and cerebrovascular disease were excluded from the study.

Anaesthetic management

Anaesthesia was induced with 5m1/kg of ideal body weight of Thiopentone supplemented with 2microgm per kg Fentanyl. Tracheal intubation was facilitated with 0.1mg/kg of Vecuronium. Anaesthesia was maintained with Isoflurane in a mixture of 02 (40%) and N20 (60%) Mechanical ventilation was conducted with Datex ohmeda Aestiva/3 smart ventilator. In control group (n=20) patient's lungs were ventilated with 40% of inspired oxygen, TV of 8m1/kg, ventilator breaths of 10breaths/min, inspiratory: expiratory ratio of 1:2, end tidal CO2 was continuously monitored and ventilation subsequently adjusted first by increasing respiratory rate and then TV in 50 m1 increments to maintain PaCO2 at level between 35-45 mmHg.In PEEP group all parameters were same in addition to extrinsic PEEP of 5cm of water. All measurements were made with patients positioned in reversed trendelenberg. Baseline measurements were performed 5mins after the induction of anaesthesia but before onset of pneumoperitoneum. A second set of measurement began 15mins after pneumoperitoneum, third set performed after 30mins after pneumoperitoneum. Final measurement performed after pneurnoperitoneum was released upon completion of surgery. Pa02, $PaCO_2$ and pH were also recorded 30mins after tracheal extubation in the recovery room, Arterial blood pressure, heart rate were recorded throughout intraoperative period.

Respiratory parameters that were recorded are- Peak airway pressure, mean airway pressure plateau airway pressure, expiratorytidal volume, expiratory minute volume, dynamic compliance and inspiratory airway resistance. Residual neuromuscular blockade was reversed with neostigmine 0.05/kg and atropine 0.02mg/kg.

Haemodynamic monitoring included Electrocardiogram for heart rate measurement and any evidence of ECG changes, invasive blood pressure monitoring (systolic blood pressure, diastolic blood pressure and mean arterial pressure) and pulse oximetry.Finally medical records and clinical notes were reviewed after hospital discharge for development of following postoperative pulmonary complications like respiratory failure requiring mechanical ventilation or delayed tracheal extubation (more than 24hrs after surgery) pneumonia, clinical pulmonary infection, atelectesis requiring intervention (bronchoscopy) and length of hospitalization. Primary outcome variable was ratio of arterial oxygen partial pressure to inspiratory oxygen concentration Pa02/Fi02 and other variables related to gas exchange, oxygenation, ventilation, respiratory mechanics and haemodynamics were reported separately for patients randomized to PEEP application as well as control group[13-16].

Results

Table 1: comparison of heart rate between no PEEP & PEEP Group

Time(Min)	Group - I	Group - II	t test group I & II
	Mean $\pm$ SD	Mean $\pm$ SD	P Value
After Intubation	75.5 $\pm$ 13.66	67.75 $\pm$ 9.95	P > 0.05
15 Min. after pneumoperitoneum	85.6 $\pm$ 19.66	77.85 $\pm$ 9.52	P > 0.05

30 Min. after pneumoperitoneum	79 ± 13.32	74.4 ± 9.84	P > 0.05
After Extubation	77.9 ± 11.30	96.9 ± 10.85	P > 0.05

Table 2 : Comparison of mean arterial pressure between no PEEP & PEEP Group

Time(Min)	Group - I	Group - II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	90.95 ± 11.26	85.75 ± 12.70	P > 0.05
15 Min. after pneumoperitoneum	100.9 ± 7.38	97.15 ± 9.65	P > 0.05
30 Min. after pneumoperitoneum	100.9 ± 4.35	98.15 ± 6.76	P > 0.05
After Extubation	97.65 ± 8.16	93.4 ± 7.06	P > 0.05

Table 3: comparison of peak airway pressure between no PEEP & PEEP Group

Time (Min)	Group - I	Group - II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	16.6 + 3.45	18.5 + 3.36	P > 0.05
15 Min. after pneumoperitoneum	19.8 + 3.23	21.95 + 2.79	P > 0.05
30 Min. after pneumoperitoneum	19.8 + 3.60	22.25 + 2.97	P > 0.05

Table 4: comparison of mean airway pressure between no PEEP & PEEP Group

Time (Min)	Group - I	Group - II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	74 ± 1.72	8.5 ± 1.67	P > 0.05
15 Min. after pneumoperitoneum	8.3 ± 1.45	9.15 ± 0.93	P > 0.05
30 Min. after pneumoperitoneum	8.5 ± 1.70	9.8 ± 1.28	P > 0.05

Table 5: comparison of expiratory minute volume between no PEEP & PEEP Group

Time (Min)	Group - I	Group - II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	4.45 ± 0.62	4.59 ± 0.56	P > 0.05
15 Min. after pneumoperitoneum	4.78 ± 0.84	5.07 ± 0.82	P > 0.05
30 Min. after pneumoperitoneum	4.92 ± 0.91	0.78 ± 0.84	P > 0.05

Table 6: comparison of PaO_2 / FiO_2 ratio between no PEEP & PEEP Group

Time (Min)	Group - I	Group – II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	450 ± 85.60	510 ± 85.39	P > 0.05
15 Min. after pneumoperitoneum	354.15 ± 80.37	428 ± 112.18	P > 0.05
30 Min. after pneumoperitoneum	341.8 ± 88.94	405 ± 101.22	P > 0.05
After Extubation	398 ± 99.15	359 ± 70.03	P > 0.05

Table 7:comparison of $PACO_2$ between no PEEP & PEEP Group

Time (Min)	Group - I	Group – II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	32.65 ± 6.24	34.6 ± 4.84	P > 0.05
15 Min. after pneumoperitoneum	34.65 ± 6.54	36.3 ± 6.24	P > 0.05
30 Min. after pneumoperitoneum	35.1 ± 6.66	37.25 ± 4.78	P > 0.05
After Extubation	35.7 ± 6.16	39.45 ± 5.83	P > 0.05

Table 8 :comparison of PAO_2 / FIO_2 RATIO BETWEEN NO PEEP & PEEP Group

Time (Min)	Group - I	Group – II	t test group I & II
	Mean ± SD	Mean ± SD	P Value
After Intubation	7.38 ± 0.067	7.38 ± 0.036	P > 0.05
15 Min. after pneumoperitoneum	7.34 ± 0.060	7.34 ± 0.050	P > 0.05
30 Min. after pneumoperitoneum	7.33 ± 0.057	7.36 ± 0.050	P > 0.05
After Extubation	7.33 ± 0.048	7.35 ± 0.051	P > 0.05

Primary outcome variable was ratio of arterial oxygen partial pressure to inspiratory oxygen concentration Pa02/Fi02 and other variables related to gas exchange, oxygenation, ventilation, respiratory mechanics and haemodynamics were reported separately for patients randomized to PEEP application as well as control group. All continuous data are expressed as mean ± SD. Comparison of two groups were done by using student's testApplying 5cm of PEEP significantly improves pulmonary gas exchange during pneumoperitoneum. It has led to a redistribution of blood flow from areas with low and zero Va/Q. This has improved both arterial oxygenation and CO2 elimination.

Statistical analysis

Data was compiled using MS excel 2007 and analysis was done with the help of Epi-Info 7 software. Frequency and percentage were calculated & statistical test (Chi Square) was applied wherever

applicable; $p<0.05$ was taken as statistically significant. All continuous data are expressed as mean ± SD.
Comparison of two groups were done by using student's test
P value <0.05 - statistically significant
P value <0.01 - highly significant.

Discussion

It appears that anesthesia and paralysis cause reduction of lung volume through a continuum related to body mass index. The reduction of lung volume is associated to an increase of the elastance of the respiratory system, equally divided between its chest wall and lung components. From our data it seems that increased intraabdominal pressure may play an important role (although not unique) in increasing the chest wall elastance and decreasing the end-expiratory lung volume. The decrease of oxygenation is associated with increase of body mass index and lung volume reduction, suggesting that a relevant lung collapse is likely present in the obese patients.

Laparoscopy induces significant hemodynamic changes and creates increases of SVR and PVR, and increase of MAP, and a reduction of C.O. in healthy as well as obese patients. This was also supported by Jean.L. Joris, who observed hemodynamic changes during laparoscopic cholecystechtomy.In our study we did find an increase in MAP and HR between both the groups but group with additional PEEP showed lesser increases in MAP and HR as compared to group without PEEP the difference were not found to be statistically significant. This could be due to decrease in central venous pressure, decrease venous return and decrease in cardiac output causing hypotension. However these effects are apparent after applying greater value of PEEP. Increase in heart rate and MAP is slightly more at the time of insufflations setting down 30 mins after insufflations returning close to baseline levels 30 mins after extubation.

Findings were similar to Alexander et al, who found that there were no significant differences seen in CVP, Pulmonary artery pressure and pulmonary capillary wedge pressure or mean arterial pressure after applying incremental values of PEEP during laparoscopic surgery.Meninger D et al, stated that application of 5cm of PEEP improves arterial oxygenation without significant difference in heart rate, mean arterial pressure and central venous pressure during prolonged penumoperitoneum. Ekman et al, observed that applying 0.49kPa of PEEP does not significantly decrease heart rate, blood pressure, pulmonary vascular resistance or stroke volume in patients undergoing elective laparoscopic sterilization.

Bagoiri F et al, states that PEEP application upto values approaching auto peep and 5cm of water above auto peep did not result in impairment pf right ventricular haemodynamics while higher levels reduced C.O. in selected patient.Dumont L et al, studied haemodynamic changes during laparoscopic gastroplasty in morbidly obese patients. They found that obese patients tolerated pneumoperitoneum surprisingly well than nonobese patients without experiencing fall in oxygenation.Sugimoto H et al, observed effects of PEEP on tissue gas tension and oxygen transport in patients who were being mechanically ventilated for acute pulmonary failure. Increasing level of PEEP does not produce significant change in mean arterial pressure, oxygen consumption and mixed venous oxygen tension.

Throughout surgery, patients with PEEP had higher peak, plateau and mean airway pressure and they were found to be statistically significant. This could be due to increase in alveolar pressures and alveolar volume and it has the potential to cause barotrauma. But in our study these pressures were low and none were increased more than 30mm Hg, sufficient to cause barotrauma. Airway pressures were lower at the time of intubation increasing in value at the time of insufflation and thereafter 30 mins after insufflation.

Francis X Whalen et al, found significant increase in peak inspiratory and mean airway pressures in recruitment group after giving increasing level PEEP as compared to control group in which fixed level of PEEP was given to all patient. Alexander et al, compared effect of PEEP and found that more than 10 cm of PEEP results in significant increase in mean airway pressure as compared to 5 cm of PEEP in control group during laproscopic surgery. S Bhalla et al, observed effect of PEEP on dynamic hyperinflation in patients with airflow limitation. Application of extrinsic PEEP greater than intrinsic PEEP may substantially aggravate lung hyperinflation.

Study showed that PEEP significantly increases intraoperative Pa02 in patients undergoing laproscopic surgery. Improvement in Pa02 was sustained in most patients for as long as endotrachael intubation and PEEP were maintained. However this effect disappeared within 30 mins of tracheal extubation. This may be due to redistribution of fluid within the alveoli and reducing intrapulmonary shunting thereby increasing arterial oxygenation. Pelosi et al, concluded that 10 cm of PEEP increases oxygenation in obese patients but not in normal subjects and oxygenation improvement is related to amount of alveolar recruitment[16]The opening of collapsed units is a function of transmural pressure.Alexander et al, reported that comparing 5cmof PEEP with 15 cm of PEEP displayed significant difference in arterial $Pa0_2$ ($P<0.05$) and highly significant difference could be found by comparing PEEP of 5cm. with 20cm. ($P<0.02$) PEEP of 15cm H_2O result in significantly more blood flow to areas with zero Va/Q and significantly more blood to lung areas with normal Va/Q. Francis X Whalen et al, observed that recruitment mannuevers resulted in significantly improved oxygenation in patients undergoing bariatic surgery. This improved oxygenation is sustained as long as intubation and PEEP was maintained but it promptly dissipates after tracheal extubation.Both $PaCO_2$ and pH were comparable in both the groups throughout the surgery and it is slightly on the higher side 30mins after extubation. The reason for this is that after creating pneumoperitoneum we had increased the respiratory rate to hyperventilate the patient as after creating pneumoperitoneum, CO_2 pressure increases in mixed venous blood causing hypercarbia. Ekman states that 0.49kPa of PEEP during laproscopy for investigation of infertility results in no net increase in $ETCO_2$ after CO_2 insufflation and it remained closer to baseline level throughout the surgery.Alexander et al, reported that during laproscopy diaphragmatic excursion is impaired and CO_2 pressure increases in mixed venous blood. However, because all patients were hyperventilated CO_2 associated effects on pulmonary ciculation were not apparent.

Applying 5cm of PEEP significantly improves pulmonary gas exchange during pneumoperitoneum. It has led to a redistribution of blood flow from areas with low and zero Va/Q. This has improved both arterial oxygenation and CO2 elimination. This improved oxygenation is related to the alveolar recruitment. The opening of collapsed units is a function of transmural pressure, which is mainly related to plateau pressure.PEEP of 5cm of water does not affect haemodynamics significantly nor it causes increase in airway pressures to that level which can cause barotraumas. Hyperventilation of the lungs decreases the chances of hypercarbia and respiratory acidosis.

Thus to summarize that positive effects of PEEP outweigh its negative effects and applying 5cm of PEEP improves oxygenation in morbidly obese patients without causing hemodynamic instability. This improved oxygenation persists throughout the surgery but it promptly dissipates after tracheal extubation. However further studies are needed to define optimal level of Tidal Volume & PEEP in obese patient to maintain respiratory mechanics & oxygenation.

Conclusion

Applying 5cm of PEEP significantly improves pulmonary gas exchange during pneumoperitoneum. It has led to a redistribution of blood flow from areas with low and zero Va/Q. This has improved both arterial oxygenation and CO_2 elimination. This improved oxygenation is related to the alveolar recruitment. The opening of collapsed units is a function of transmural pressure, which is mainly related to plateau pressure.PEEP of 5cm of water does not affect haemodynamics significantly nor it causes increase in airway pressures to that level which can cause barotraumas. Hyperventilation of the lungs decreases the chances of hypercarbia and respiratory acidosis.

What this study add to existing knowledge

Thus to summarize that positive effects of PEEP outweigh its negative effects and applying 5cm of PEEP improves oxygenation in morbidly obese patients without causing hemodynamic instability. This improved oxygenation persists throughout the surgery but it promptly dissipates after tracheal extubation. However further studies are needed to define optimal level of Tidal Volume & PEEP in obese patient to maintain respiratory mechanics & oxygenation.

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