Section: Anaesthesia

Original Research Article

APPLICATION OF EXTRINSIC POSITIVE END EXPIRATORY PRESSURE DURING CONTROLLED MECHANICAL VENTILATION IN LAPAROSCOPIC CHOLECYSTECTOMY AND ITS EFFECTS ON RESPIRATORY MECHANICS AND ARTERIAL OXYGENATION

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Abstract

Background: Laparoscopic surgery is a modern advancement in medical science that has taken over open procedures wherever feasible. This study was done to evaluate effects of extrinsic positive end-expiratory pressure on respiratory mechanics, arterial blood gases and hemodynamics on obese patients undergoing laparoscopic cholecystectomy. **Materials and Methods:** This prospective, randomized controlled study to evaluate the effects of extrinsic PEEP on respiratory mechanics, arterial blood gases and hemodynamics during laparoscopic cholecystectomy was conducted on forty obese patients. Patients were randomly allocated into two groups (n=20), Group I with no PEEP and Group II with PEEP (5 cm of water). The variables studied were Respiratory mechanics (Peak, Mean and Plateau Airway Pressure, Airway Resistance, Dynamic Compliance, Expiratory Tidal volume and Expiratory Minute Volume), Oxygenation Index (PaO2/FiO2 - Partial Pressure of Oxygen in blood & Fractional Concentration of inspiratory oxygen ratio), PaCO2 (Partial Pressure of CO2 in blood), pH and Hemodynamic changes (Heart Rate and Mean Arterial Pressure) at different intervals. **Result:** Group II patients demonstrated higher peak, mean & plateau airway pressures but below the threshold to cause barotrauma; higher Compliance, decrease in Resistance and significant increase in PaO2 indicating better pulmonary gas exchange while Heart Rate and Mean Arterial Pressure remained stable. Expiratory tidal volume and minute volume, PaCO2 and pH were comparable between the two groups. **Conclusion:** PEEP appears to be a beneficial addition to our ventilatory strategy in improving pulmonary gas exchange, especially in obesity, laparoscopy and mechanical ventilation. However further studies are needed to define optimal levels of PEEP to improve oxygenation while maintaining respiratory mechanics and hemodynamics.

INTRODUCTION

Laparoscopic surgery has become the most popular choice of procedure among clinicians and patients alike and gained worldwide acceptance. It is preferable over conventional open procedure since it offers several benefits like smaller incision, decreased post operative pain, early ambulation, minimal post operative scar & early return to normal life.[1] Abdomino-pelvic surgeries like cholecystectomy, appendicectomy, sleeve gastrectomy, hysterectomy and diagnostic procedures are preferred laparoscopically 2 over open approach now-a-days, both by doctors and patients.[2-4]

Laparoscopic Cholecystectomy requires pneumoperitoneum which could result in hemodynamic and respiratory adverse effects like impeding diaphragmatic movement, increased peak inspiratory pressure and pulmonary resistance thereby decreasing lung compliance.[5,6] These combined with reverse trendelenburg position, systemic Carbon dioxide (CO2) absorption, general anesthesia and obesity, the challenges become

multitude for the anaesthesiologist who has to maintain cardiovascular and respiratory function.[3]
Since there is a higher risk of hypoxemia, hypercarbia, acidosis and hyperdynamic circulation in obese patients during laparoscopic surgery, respiratory mechanics, blood gases and hemodynamics must be monitored closely to identify and optimally manage mechanical and ventilatory effects.[4]
Positive end expiratory pressure (PEEP) works by preventing alveoli from collapsing and even reopening the collapsed ones, decreasing intrapulmonary shunting and increasing pulmonary compliance,[5] thereby improving gas exchange. Because of beneficial effects of PEEP on pulmonary physiology and gas exchange, we planned this study to evaluate effects of extrinsic PEEP on respiratory mechanics, arterial blood gases and hemodynamics on patients undergoing laparoscopic cholecystectomy.

Aims & Objectives

To study and compare the effects of PEEP in obese patients undergoing laparoscopic cholecystectomy under controlled mechanical ventilation as follows:

1. Respiratory mechanics in terms of Peak, Mean and Plateau Airway Pressure, Airway Resistance, Dynamic Compliance, Expiratory Tidal volume and Expiratory Minute Volume
2. Oxygenation Index in terms of PaO2/FiO2 (Partial Pressure of Oxygen in blood/ Fractional Concentration of inspiratory oxygen ratio), PaCO2 (Partial Pressure of CO2 in blood), pH at different intervals
3. To study the Hemodynamic changes in terms of Heart Rate (HR) and Mean Arterial Pressure (MAP) at different intervals

MATERIALS AND METHODS

This prospective, randomized controlled study to evaluate the effects of extrinsic PEEP on respiratory mechanics, arterial blood gases and haemodynamics during laparoscopic cholecystectomy was conducted after Ethics Committee approval. Forty obese patients (BMI>40kg/m2 of ASA grade 1 or 2) aged 30 – 50 yrs were included in the study. After obtaining informed consent, 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

Exclusion Criteria

Patients with cerebrovascular disease, uncontrolled hypertension, heart block, pulmonary disease like Chronic Obstructive Pulmonary Disease (COPD) or Bronchial asthma were excluded from the study.
All patients had a detailed pre-anaesthesia check up done and preoperative orders given as routinely practised for all patients in our institution. Anaesthesia was induced with intravenous Midazolam (1 mg), Fentanyl (2µg/kg), Propofol (1.5 mg/kg) and Vecuronium (0.1mg/kg). After tracheal intubation, mechanical ventilation was conducted with Datex ohmeda Aestiva/3 smart ventilator in all patients. Anesthesia was maintained with Isoflurane, O2 (40%) and N2O (60%) to keep the MAC (Minimum Alveolar Concentration) at 1. After completion of surgery, residual neuromuscular blockade was reversed with Neostigmine (0.05/kg) and Atropine (0.02mg/kg).
In Group I (n=20), with TV (8 ml/kg), RR (10/min), inspiratory: expiratory ratio (I:E) 1:2, end tidal CO2 (EtCO2) was continuously monitored. Ventilatory parameters were adjusted to maintain EtCO2 between 35-45 mmHg.
In Group II (n=20) all ventilatory parameters were the same, with the addition of extrinsic PEEP (5cm of water).
Baseline measurements were made 5 minutes after induction of anaesthesia but before onset of pneumoperitoneum in reversed trendelenberg position, then again after 15 minutes and 30 minutes. The final reading was taken after completion of surgery upon pneumoperitoneum release.
Respiratory parameters recorded were - Peak airway pressure, mean airway pressure, plateau airway pressure, expiratory tidal volume, expiratory minute volume, dynamic compliance and inspiratory airway resistance.
Primary outcome variable was ratio of arterial oxygen partial pressure to inspiratory oxygen concentration (PaO2/FiO2), PaCO2 and pH which were repeated 30 minutes after tracheal extubation.
Haemodynamic monitoring included Electrocardiogram (ECG) for heart rate, any fresh changes, invasive blood pressure monitoring (systolic and diastolic blood pressure, mean arterial pressure) and pulse oximetry (SpO2).
All continuous data are expressed as mean ± SD. Comparison of two groups were done by using student's t test. P value <0.05 - statistically significant, P value <0.01 - highly significant.

RESULTS

[Table 1] shows distribution of cases according to age group among the two groups. The majority of patients were in 35-45 years age group. Mean age of patients was comparable in both groups.

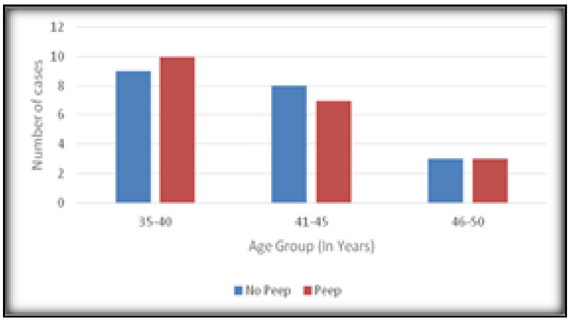

Figure 1: Distribution of patients according to Age

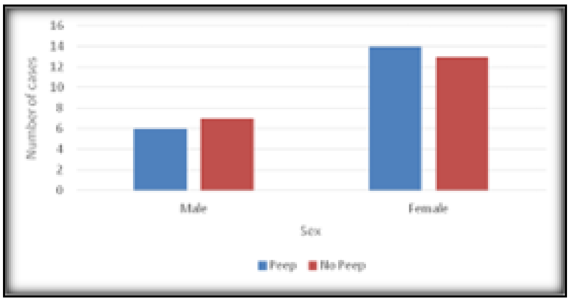

Figure 2: Distribution of patients according to Sex

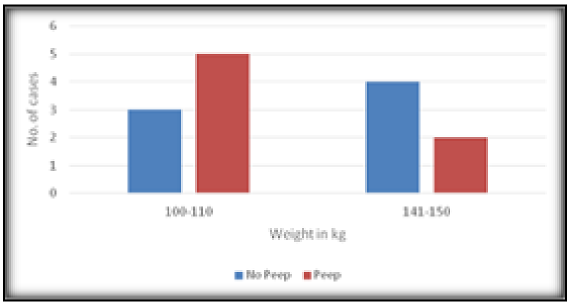

Figure 3: Distribution of patients according to Weight

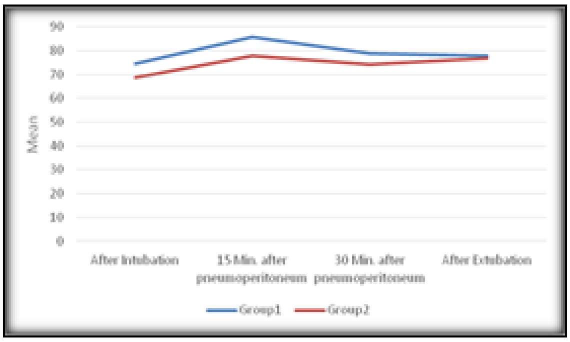

Figure 4: Comparison of Heart Rate (per minute)

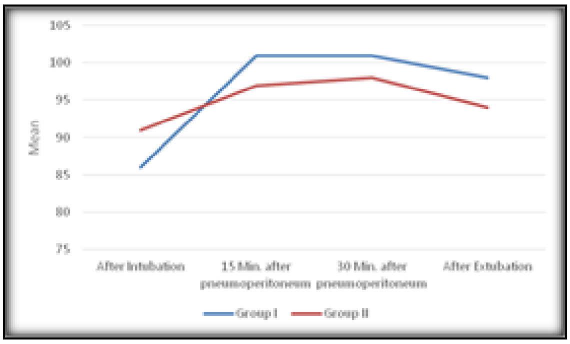

Figure 5: Comparison of Mean Arterial Pressure in mmHg

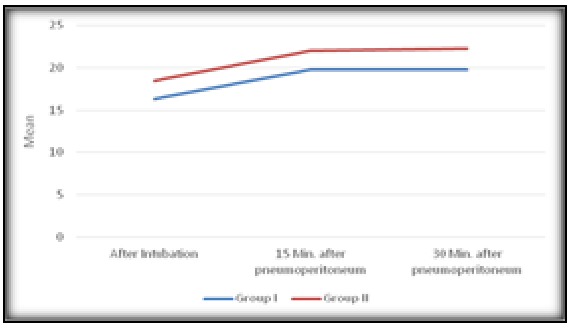

Figure 6: Comparison of Peak airway pressure(mmHg)

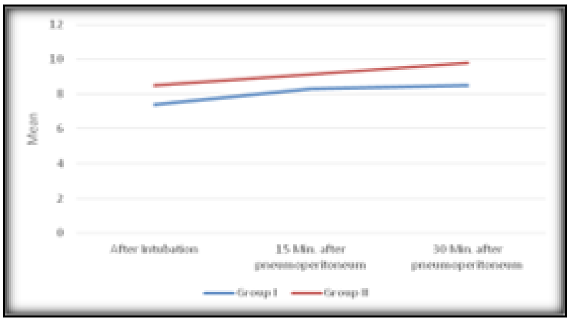

Figure 7: Comparison of Mean Airway Pressure (mmHg)

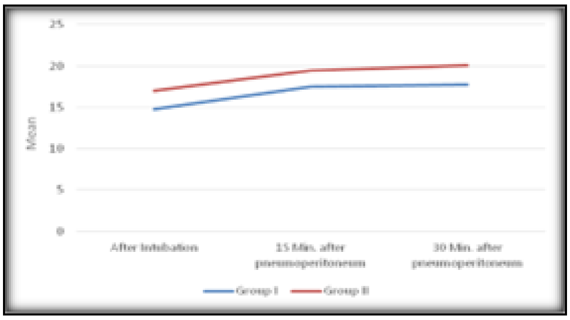

Figure 8: Comparison of Plateau Airway Pressure (mmHg)

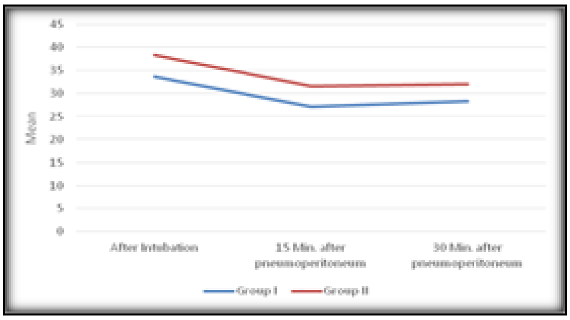

Figure 9: Comparison of Compliance

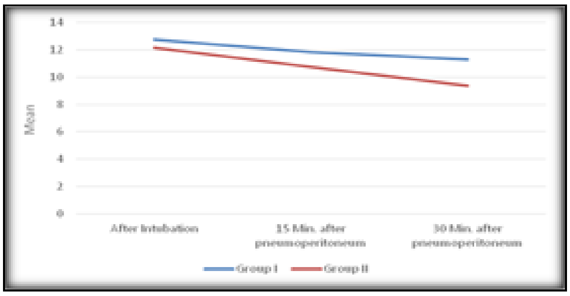

Figure 10: Comparison of Resistance

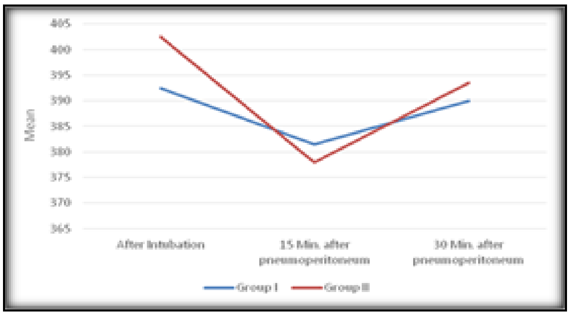

Figure 11: Comparison of Expiratory Tidal Volume (mL)

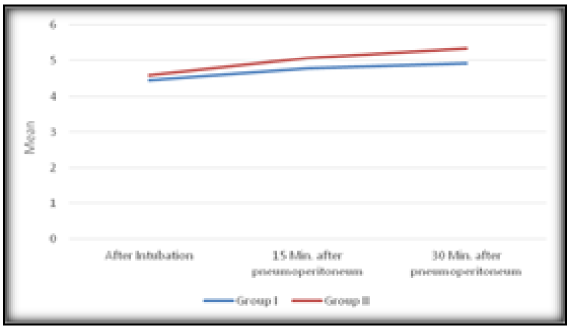

Figure 12: Comparison of Expiratory Minute Volume (L)

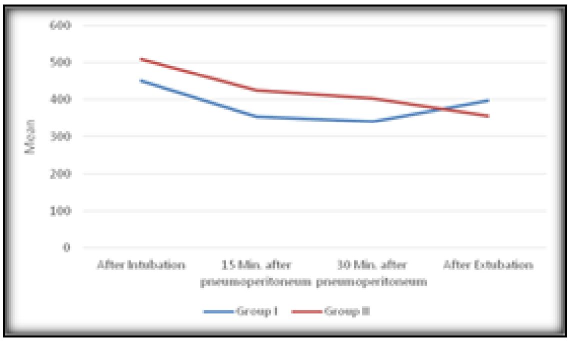

Figure 13: Comparison of PaO2 /FiO2

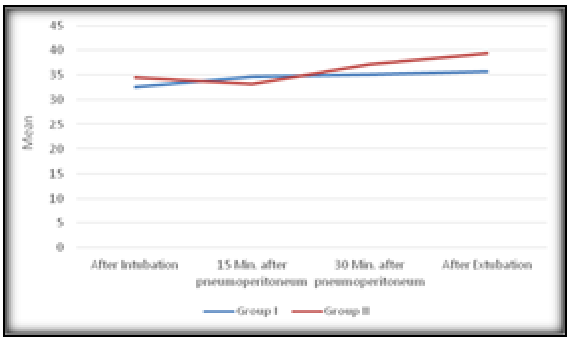

Figure 14: Comparison of PaCO2 (mmHg)

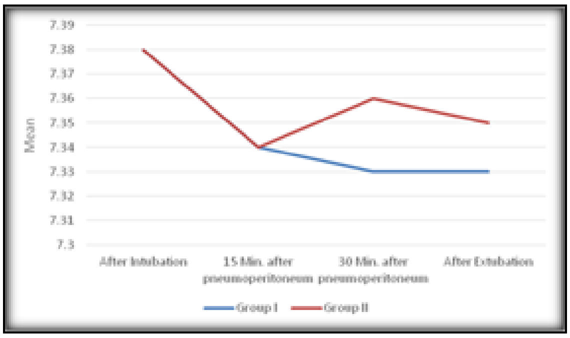

Figure 15: Comparison of pH

Table 1: Distribution of patients according to Age.

Age Group (In Years)	No Peep - No. (%)	Peep - No. (%)
35-40	9 (45)	10(50)
41-45	8(40)	7(35)
46-50	3(15)	3(15)
Total	20(100)	20(100)
Mean	42.3	41.35
± SD	± 5.32	± 5.37

[Table 2] below shows distribution of cases according to sex. Female to Male ratio is 2:1. Out of 40 patients females were 67.5% and males were 32.5%.

Table 2: Distribution of patients according to Sex

Sex	Group I No. (%)	Group II No. (%)
Male	6 (30)	7(35)
Female	14(70)	13(65)
Total	20 (100%)	20 (100%)

Table 3: Distribution of patients according to Weight

Weight (in Kg)	Group I - No. (%)	Group II - No. (%)
100-110	3(15)	5(25)
111-120	5(25)	5(25)
121-130	6(30)	6(30)
131-140	2(10)	2(10)
141-150	4(20)	2(10)
Total	20 (100)	20 (10%)
Mean	125.2	120.1
± SD	± 13.6	± 13.26

The majority of patients weighed in the range of 110-130 kg. Mean weight was comparable in two groups.

Table 4: Comparison of Heart Rate (per minute)

Time	Group I	Group II	t test group I & II
	Mean ± SD	Mean ± SD	P value
After intubation	74.5 ± 20.03	68.75 ± 9.95	P > 0.05
15 min after pneumoperitoneum	85.6 ± 19.66	77.85 ± 9.52	P > 0.05
30 min after pneumoperitoneum	79 ± 13.32	74.4 ± 9.84	P > 0.05
After extubation	77.9 ± 11.3	76.9 ± 10.85	P > 0.05

Table 5: Comparison of Mean Arterial Pressure in mmHg

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	86 ± 11.32	91 ± 12.72	P > 0.05
15 min after pneumoperitoneum	101 ± 7.38	97 ± 9.65	P > 0.05
30 min after pneumoperitoneum	101 ± 4.35	98 ± 6.8	P > 0.05
After extubation	98 ± 8.13	94 ± 7.05	P > 0.05

Table 6: Comparison of Peak airway pressure(mmHg)

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	16.3 ± 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 7: Comparison of Mean Airway Pressure (mmHg)

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	7.4 ± 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 8: Comparison of Plateau Airway Pressure (mmHg)

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	14.75 ± 3.41	16.95 ± 3.33	P < 0.05
15 min after pneumoperitoneum	17.5 ± 3.05	19.45 ± 2.54	P < 0.05
30 min after pneumoperitoneum	17.7 ± 3.16	20.1 ± 3.33	P < 0.05

Table 9: Comparison of Compliance

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	33.7 ± 7.37	38.35 ± 7.25	P < 0.05
15 min after pneumoperitoneum	27.25 ± 5.86	31.65 ± 7.27	P < 0.05
30 min after pneumoperitoneum	28.35 ± 5.03	32 ± 8.07	P < 0.05

Table 10: Comparison of Resistance

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	12.75 ± 4.06	12.15 ± 2.81	P > 0.05
15 min after pneumoperitoneum	11.85 ± 3.31	10.75 ± 2.26	P > 0.05
30 min after pneumoperitoneum	11.3 ± 2.43	9.4 ± 1.53	P > 0.05

Table 11: Comparison of Expiratory Tidal Volume (mL)

Time	Group I	Group II	t test group I & II
	Mean ± SD	**Mean ± SD**	**P value**
After intubation	392.5 ± 41.53	402.5 ± 63.56	P > 0.05
15 min after pneumoperitoneum	381.5 ± 39.50	378 ± 59.70	P > 0.05
30 min after pneumoperitoneum	390 ± 36.12	393.5 ± 70.80	P > 0.05

Table 12: Comparison of Expiratory Minute Volume (L)

Time	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	5.35 ± 0.77	P > 0.05

Table 13: Comparison of PaO2 /FiO2

Time	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 ± 80.37	426 ± 112.08	P < 0.05
30 min after pneumoperitoneum	342 ± 60.94	404 ± 100	P < 0.05
After extubation	398 ± 99.15	357 ± 69.56	P < 0.05

Table 14: Comparison of PaCO2 (mmHg)

Time	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	33.3 ± 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 15: Comparison of pH

Time	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	7.48 ± 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

DISCUSSION

Heart rate and mean arterial pressure: Laparoscopy induces significant haemodynamic changes like increase in Systemic Vascular Resistance (SVR), Pulmonary Vascular Resistance (PVR) and MAP, and reduction in Cardiac Output (CO) in healthy as well as obese patients. This was supported by Jean.L. Joris in their study on 15 nonobese patients during laparoscopic cholecystectomy under general anesthesia.[7]

In our study we found an increase in MAP and HR in both the groups, but group II (PEEP) showed lesser increase as compared to group I although they were not found to be statistically significant. This could be due to decrease in central venous pressure (CVP), venous return (VR) and CO causing hypotension after PEEP. Increase in HR and MAP was slightly more at insufflation, settling down 30 minutes later and returning close to baseline 30 minutes after extubation in both groups.

These findings were similar to Loeckinger et al, who found that there were no significant differences seen in CVP, Pulmonary artery pressure and pulmonary capillary wedge pressure or MAP after applying incremental values of PEEP during laparoscopic surgery.[8]

Meninger et al stated that application of 5cm of PEEP improves arterial oxygenation without significant difference in HR, MAP and CVP during prolonged pneumoperitoneum.[9]

Ekman et al observed that applying 0.49 kPa of PEEP does not significantly decrease HR, BP, PVR and SV in patients undergoing elective laparoscopic sterilization.[10]

Bagoiri F et al found that PEEP up to values approaching auto peep and 5cm of water above auto peep did not result in impairment of right ventricular haemodynamics while higher levels reduced C.O. in selected patients.[11]

Dumont et al studied respiratory mechanics during laparoscopic gastroplasty in morbidly obese patients and found that obese patients tolerated pneumoperitoneum surprisingly well as compared to non obese patients, without any change in oxygenation.[12]

Sugimoto et al observed effects of PEEP on tissue gas tension and oxygen transport in patients mechanically ventilated for acute pulmonary failure. Increasing level of PEEP does not produce significant change in MAP, oxygen consumption, mixed venous oxygen tension, pH or base excess, and proving that peripheral tissue oxygenation is not impaired.[13]

Airway Pressures: Group II had higher peak, plateau and mean airway pressure in comparison with Group I, and it was found to be statistically significant. This could be due to increase in alveolar pressure and volume which are potential causes of barotrauma. In our study these airway pressures were low and none increased more than 30mm Hg to lead to any barotrauma. Airway pressures were low at the time of intubation, increased at insufflation and remained so 30 minutes later in both groups. The opening of collapsed units is a function of transmural pressure, which is mainly related to plateau pressure.

Whalen et al found significant increase in peak inspiratory and mean airway pressures in alveolar recruitment group after giving increasing level PEEP as compared to control group in which fixed level of PEEP was given to all patients.[14]

Loeckinger et al compared effect of incremental PEEP and found that PEEP (in cm of water) of more than 10 as compared to 5, results in significant increase in mean airway pressure during laparoscopic surgery.[8]

Bhall 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 hyper inflation.[15]

Compliance and Resistance: There was statistically significant difference in Compliance, while a decrease in Resistance (group II) was found out to be not significant statistically. As our study patients were obese, they have lower respiratory compliance, higher resistance and reduced FRC, and contrary to wide belief, normal chest wall compliance. Hence this difference in respiratory mechanics may result in decrease in transpulmonary pressure which may decrease effectiveness of PEEP therapy and also may decrease likelihood of adverse hemodynamic effects. Compliance was more just after intubation and decreased 15 minutes after insufflation and increased slightly 30 minutes after insufflation.

Pelosi et al stated that 10 cm of PEEP significantly decreased maximum resistance of respiratory system mainly by reducing lung component and this effect was more evident in obese patients as compared to normal patients.[5]

Whalen et al reported that recruitment manoeuvres result in significantly increased dynamic respiratory compliance and a decrease in inspiratory airway resistance as compared to control group during bariatric surgery.[14]

Expiratory tidal volume and expiratory minute volume were comparable between the two groups in our study.

Arterial Oxygenation (PaO2/FiO2): Our study showed that PEEP significantly increases intraoperative PaO2 which was sustained in most patients for as long as endotracheal intubation and PEEP were maintained. However this effect disappeared within 30 minutes of extubation. PEEP may be causing alveolar recruitment, redistribution of fluid within the alveoli and reduced 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. This improvement is related to amount of alveolar recruitment since the opening of collapsed units is a function of transmural pressure.[15]

Loeckinger et al reported that comparing PEEP (in cm of water) of 5 with 15, displayed significant difference in arterial PaO2 ($p<0.05$) and highly significant difference was seen in comparison with 20 ($p<0.02$). PEEP of 15 resulted in significant gas exchange augmentation with only modest hemodynamic depression.[8]

Whalen et al observed that recruitment manoeuvres resulted in significantly improved oxygenation in patients undergoing bariatric surgery which sustained as long as intubation and PEEP were maintained, but promptly dissipated after tracheal extubation.[14]

PaCO2, pH: PaCO2 and pH were comparable in both the groups throughout the surgery and slightly on the higher side 30 minutes after extubation. The reason for this could be that after creating pneumoperitoneum the minute ventilation was increased to maintain EtCO2 between 35-45 mmHg.

Ekman states that 0.49 kPa of PEEP during laparoscopy for investigation of infertility results in no net increase in EtCO2 after CO2 insufflation and it remained close to baseline level throughout the surgery.[10]

Loeckinger et al reported that during laparoscopy, diaphragmatic excursion was impaired and PCO2 increased in mixed venous blood. However, because all patients were hyperventilated, CO2 associated effects on pulmonary circulation were not apparent.[8]

CONCLUSION

PEEP appears to be a beneficial addition to our ventilatory strategy in improving pulmonary gas exchange, especially in obesity, laparoscopy and mechanical ventilation.

It significantly improves pulmonary gas exchange during pneumoperitoneum by redistribution of blood flow from areas with low and zero Va/Q and alveolar recruitment, hence improving both arterial oxygenation and CO2 elimination. This decreases the chances of hypercarbia and respiratory acidosis.

PEEP of 5cm of water does not affect haemodynamics significantly nor does it cause increase in airway pressures to a level which can cause barotrauma.

However further studies are needed to define optimal levels of PEEP to improve oxygenation while maintaining respiratory mechanics and hemodynamics.

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