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Assessment of Positive End-expiratory Pressure on Diaphragmatic Functions in Patients Undergoing Laparoscopic Colorectal Surgery Using POCUS: A Randomized, Comparative Study

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Abstract **Original Research Article**

Background and Aim**:** Atelectasis due to impaired respiratory mechanics and pulmonary gas exchange during general anaesthesia is compounded by alteration in chest wall mechanics due to compression resulting from pneumoperitoneum and position. PEEP has shown to counterbalance the diaphragm cranial shift increasing FRC and decreasing respiratory system elastance. This study aimed to determine the effect of PEEP on diaphragmatic functions in patients undergoing laparoscopic colorectal surgery using POCUS. ***Method:*** A prospective, randomized, comparative study was conducted between September 2018 and August 2019 after obtaining institutional ethical clearance. 90 patients fulfilling the inclusion criteria were allocated into three groups of 30 patients each. Standard anesthesia protocol was used for all three groups. Group I received mechanical ventilation without PEEP, group II received PEEP of 5 cm of H_2O, and group III received PEEP of 10 cm of H_2O. Excursion of diaphragm was measured using USG before induction of anesthesia, after pneumoperitoneum, after Trendelenburg position, every hour thereafter until completion of surgery, after recovery and 6 hour postoperatively. The vitals and lung function were recorded. ***Result:*** Amongst three group of patients with statistically similar age, sex, BMI and other confounding parameters, diaphragmatic excursion was lowest in Group I followed by Group II and maximum in Group III. The difference was statistically significant but at the cost of high mean PIP in Group III. ***Conclusion:*** In our study, PEEP of 5 cm of H_2O was found effective in preserving diaphragmatic excursion and reducing compression atelectasis during laparoscopic colorectal surgeries.

Keywords: Atelectasis, anaesthesia, pneumoperitoneum, PEEP, USG, Trendelenburg.

INTRODUCTION

Laparoscopic approach for colorectal cancer resections has emerged from the stage of infancy with oncological concern to routine practice in the last two decades. Several randomized controlled trials and meta-analysis have concluded that laparoscopic resections are associated with rapid recovery and equivalent oncologic outcomes compared to open surgery in Colo-rectal malignancies [1].

The laparoscopic approach requires prolonged Trendelenburg's position of the patient and intraabdominal insufflation of CO_2, both of which affect the anaesthetic management of the patient. Trendelenburg's position alters the position of diaphragm due to cephalad displacement of intestinal content which is compounded by the increase in intraabdominal pressure due to CO_2 insufflation resulting to respiratory changes like decreased vital capacity and functional residual capacity (FRC), reduced respiratory compliance and formation of atelectasis in the dependent lung regions [2-6].

Following induction of general anaesthesia, atelectasis develops within minutes and is a significant factor of intraoperative gas exchange abnormalities [7, 8]. It is present in 90% of all patients under general anaesthesia without positive end-expiratory pressure (PEEP) [9, 10]. Positive end-expiratory pressure (PEEP) is a mechanical manoeuvre which increases functional residual capacity (FRC) and prevents airway collapse hence reducing atelectasis and resultantly improves oxygenation during pneumoperitoneum.

Studies have demonstrated that application of PEEP alone has few beneficial effects on regional or overall oxygenation during laparoscopic lower abdominal surgery [11].

Point-of-care ultrasonography (POCUS) is a sonographic examination which can be performed intraoperatively and can be used to evaluate diaphragmatic thickness and movement [12]. The test is non-invasive, reproducible, readily accessible in operating theatres, and provides information regarding diaphragmatic muscle movement, thickness, and echogenicity [13].

The present study was designed to evaluate the effects of PEEP on diaphragmatic functions during pneumoperitoneum and the Trendelenburg position in patients undergoing laparoscopic colorectal surgery using POCUS.

Material and Method

The current study was a prospective, randomized, comparative study, conducted in the Department of Anaesthesiology and Critical Care, Indira Gandhi Institute of Medical Sciences, Patna from September 2018 to August 2019 after obtaining approval from the institutional review board and ethics committee.

Based on previous study, with alpha error of 0.05 and a confidence level of 85%, a sample size of 90 patient was calculated using the formula:

Sample size (n) = N*X/(X+N-1), where $X = Z_{\alpha/2}^{2} * p * (1-p)/MOE^{2}$

Study population included patients undergoing laparoscopic colorectal surgery under general anaesthesia between the age group of 18-70 years and with ASA grade I or II. Patients who failed to give consent for study, BMI ≥ 30 Kg/m^2, previous history of abdominal surgery, who underwent conversion, or with known history of pulmonary disease were excluded from the study cohort.

The patients following evaluation by surgical team and investigations including pulmonary function test underwent pre anaesthetic check-up. Using computer generated random numbers the patients were randomised into three groups of 30 patients each, Group I (mechanical ventilation without PEEP), Group II (PEEP of 5 cm of H_2O), and Group III (PEEP of 10 cm of H_2O). An informed written consent for participation in the study was obtained from the patient and the patient was posted for surgery.

On the day of surgery, in the operative room standard monitoring was commenced and a wide bore 18G IV access was secured. A lumbar epidural catheter was inserted under strict aseptic precaution at lumbar interspace 2-3 using 18G Touhy needle. A test dose of 3 mL lidocaine 1% with 1:200,000 adrenaline was injected, and the catheter was fixed after confirmation of correct placement. Following preoxygenation with 100% oxygen via a facemask for 3-5 min, patients were induced with fentanyl 2 μg/kg, propofol 2 mg/kg, and atracurium 0.5 mg/kg intravenously. Intubation with suitable sized oral cuffed tube was done and mechanical ventilation commenced in volume-controlled mode with tidal volume at 8 mL/kg body weight, and respiratory rate of 12 breaths/min to maintain end tidal CO_2 ($EtCO_2$) between 33 and 36mmHg. Maintenance was done with sevoflurane 1.5%-2.0% in 50% O_2 with air, and atracurium. Intraoperative analgesia was maintained via infusion of epidural bupivacaine 0.25% at a rate of 6-8 mL/hour and fentanyl IV infusion 1 μg/kg/h.

Central venous access was then obtained. Pneumoperitoneum was created using CO_2 and the intraabdominal pressure was maintained at 12 mmHg at all times.

The randomised patients were then subjected to mechanical ventilation without PEEP (Group I), with PEEP of 5 cm H_2O (Group II) and with PEEP of 10 cm H_2O (Group III).

Sonosite M Turbo USG machine with a phase array transducer (1-5 MHz) P 21-X with scan depth 35 cm was used to measure the diaphragmatic thickness and excursion. Probe was placed in right subcostal area between the midclavicular and anterior axillary line (Figure-1). Guided by the liver as reference acoustic window, the probe was moved to identify the diaphragm which appears as a hypoechoic muscle enclosed by two echogenic lines representing the pleura and the peritoneum.

Fig-1: Use of phase array probe/transducer to measure diaphragmatic function

At end-expiratory phase the thickness of the diaphragm was measured perpendicular to the muscle (normal diaphragmatic thickness being 0.17 cm - 0.20 cm for men and 0.13 cm-0.15 cm for women). The change in thickness (diaphragmatic fraction) was calculated using the following equation:

(End inspiratory thickness - End-expiratory thickness)
End expiratory thickness

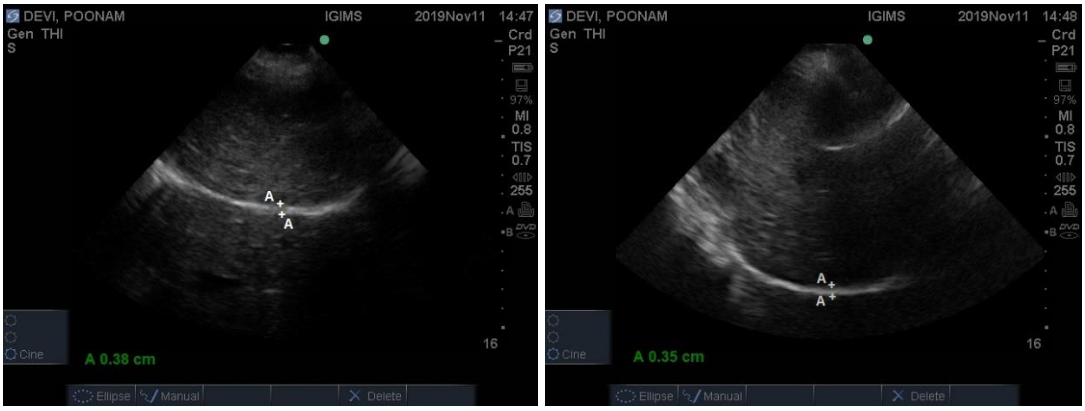


Fig-2: Diaphragmatic thickness at (A) End inspiration and (B) End expiration.

The change in thickness is expressed as a percentage with its lower limit of 20%. Diaphragmatic mobility was evaluated by determining the craniocaudal displacement of the diaphragm using M-mode ultrasound probe positioned in the infra-hepatic region. The normal upper limits during maximal inspiratory effort are approximately 4.7 cm in male and 3.7 cm in female (higher and lower values have also been reported) and the lower limits are 1 cm in male and 0.9 cm in female. Basal atelectasis was documented bilaterally through subcostal view and is presented as absence of horizontal A lines, appearance of vertical B lines, or hypoechoic areas with or without air bronchogram.

At the end of the surgery, all inhalational were discontinued and the patients were extubated following reversal with intravenous 0.05 mg/kg neostigmine and 40 µgm/kg glycopyrolate. The patients were then shifted to the surgical intensive care unit for postoperative management.

The demographic data, anesthesia time (min), pneumoperitoneum duration (min), vital parameters at every 15 mins, excursion of the diaphragm at the dome (before the induction of anesthesia, after pneumoperitoneum, after adopting the head-down position, every hour thereafter until evacuation of the abdomen, after recovery, and 6 hr post-surgery), peak inspiratory pressures (immediately after the initiation of mechanical ventilation, after pneumoperitoneum, after adopting the Trendelenburg position and 2 hr thereafter), atelectasis and diaphragmatic thickness and complications if any in the form of pneumothorax, emphysema were recorded.

The primary outcome measured was change in diaphragmatic excursion. The secondary outcomes measured were hypoxia and associated complications.

Data expressed as mean ± standard deviation, frequency, or frequency and percentage. Statistical Package for the Social Sciences version 20 (IBM, Armonk, NY, USA) was used for statistical analysis. Independent sample t-test was used to analyse quantitative data. Qualitative data analysed using Chi-Square test. P value < 0.05 was considered statistically significant.

RESULTS

A total of 102 patients were recruited in the study. 12 patients were dropped from the cohort following conversion to open surgery, deviation in intraoperative anaesthesia protocol, failure to follow up, mortality in early post-operative period and finally data of 90 patients were analysed.

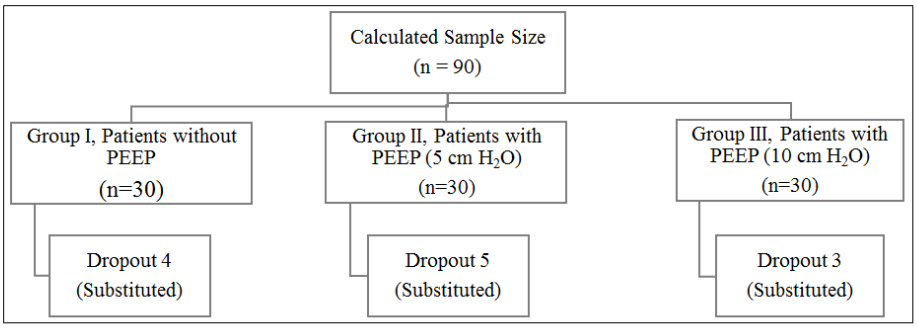


Fig-3: Case Distribution

Four patients (3 conversion to open surgery, 1 mortality in early post-operative period) were dropped from study cohort in group I, five patients (5 conversion to open surgery) were excluded from group II and three patients (2 conversion to open surgery, 1 mortality in early post-operative period).

Table-1: Demographic parameters, total anaesthesia and pneumoperitoneum time across the three group

Parameters	Group I	Group II	Group III
Age (years)	56.09±9.04	57.18±8.79	56.34±9.58
Sex (M:F)	18:12	15:15	16:14
BMI (Kg/m^2)	27.18±1.12	26.89±1.33	27.00±1.24
Anaesthesia Time (min)	257.52±24.05	261.56±22.56	254.45±27.45
Pneumoperitoneum Time (min)	148.89±11.89	150.45±9.44	147.89±12.58

The three study groups were comparable in terms of age, sex and BMI distribution and there was no statistical difference in total anaesthesia time and pneumoperitoneum time across the three group (P value being 0.895 and 0.569 respectively).

The vital parameters including CVP, SPO_2, $EtCO_2$, mean arterial blood pressure were comparable with no statistically significant difference amongst the three-study population.

Table-2: Mean heart rate variation amongst the three groups

	Group I	Group II	Group III	P Value
Pre Induction	82.02±4.01	81.78±4.18	83.21±5.23	0.149
15 min	80.34±5.43	78.54±4.32	78.11±4.89	0.047
30 min	79.92±4.23	78.65±3.12	78.05±3.15	0.043
45 min	79.21±4.11	78.23±4.35	79.01±4.27	0.089
60 min	78.56±5.05	78.02±4.98	77.23±5.96	0.162
75 min	78.12±4.29	77.85±4.39	77.79±4.21	0.110
90 min	78.84±4.11	77.99±4.58	78.02±4.67	0.096
105 min	79.81±5.27	78.57±5.31	79.21±5.11	0.129
120 min	79.44±4.21	79.01±4.28	78.83±4.87	0.264
135 min	80.27±4.44	79.41±4.23	79.29±4.77	0.157
150 min	79.45±5.28	79.87±5.73	78.99±4.23	0.097
165 min	79.28±5.81	79.27±5.74	78.75±4.56	0.049
180 min	78.68±5.17	78.86±4.12	78.10±4.74	0.144
195 min	78.44±7.74	78.08±5.23	77.20±5.54	0.057
210 min	78.54±5.27	78.41±2.27	77.00±4.12	0.084
225 min	78.98±4.85	78.20±4.51	77.04±3.76	0.021
240 min	78.71±4.23	78.12±4.74	77.04±3.49	0.945
255 min	79.12±4.77	78.54±5.21	77.27±3.71	0.004
270 min	78.87±4.21	78.10±4.04	77.87±3.97	0.057
295 min	78.65±3.99	78.05±4.00	77.78±4.27	0.751

Mean heart rate decreased in all the three groups when compared to pre induction heart rate however the decrease was more in patients of group III compared to group I. The variation of mean heart rate in the three group was statistically significant at 15, 30, 165, 225 and 255 minutes.

Table-3: Mean excursion of diaphragm

	Group I	Group II	Group III	P Value
Pre Induction	3.51±0.36	3.49±0.28	3.51±0.14	0.659
Post Pneumoperitoneum	3.10±0.21	3.19±0.34	3.21±0.21	0.876
After Trendelenburg	2.64±0.34	2.96±0.31	3.04±0.33	0.001
2 hrs after Trendelenburg	2.60±0.29	2.93±0.27	2.99±0.32	0.000
Post Extubation	3.07±0.24	3.16±0.21	3.18±0.28	0.012
6 hour Post Op	3.39±0.19	3.43±0.13	3.45±0.28	0.002

In pre induction phase and in the post pneumoperitoneum phase, the mean excursion of diaphragm was similar in all the three study groups. However, statistically significant difference in movement of diaphragm was observed in three group following positioning and during recovery. The excursion was significantly lower in group I compared to group II and III, following positioning and 2 hrs post positioning. While doing pairwise comparison the difference was significant for group II and group III post positioning and 2 hrs post positioning. Following extubation and 6 hrs post-operative the diaphragmatic movement was significantly lower in group I compared to group II and III. Pairwise comparison between the diaphragmatic excursion in post intubation and 6 hrs post op between group II and III decreased diaphragmatic movement in group II than group III, but the difference was not significant.

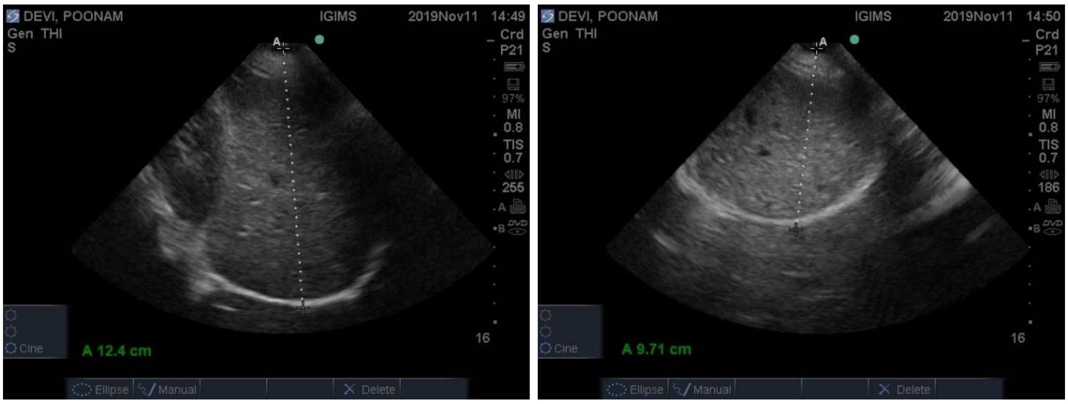
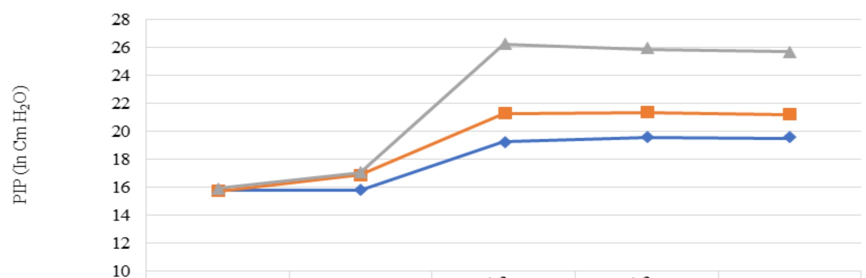


Fig-4: Measurement of diaphragmatic excursion

In the study, there was no statistically significant difference in diaphragmatic thickness amongst the three group. In group II and III, the peak inspiratory pressure increased significantly after PEEP compared to group I, however there was no significant difference in PIP when compared for group I and II. The PIP was significantly higher in group III when compared with group I and II.



	Before PEEP	After PEEP	After pneumoperitoneum	After Trendelenburg position	2 hours after positioning
Group I	15.82	15.78	19.23	19.56	19.51
Group II	15.74	16.89	21.23	21.31	21.19
Group III	15.91	17.03	26.23	25.84	25.67

Fig-5: Positive Inspiratory Pressure (PIP) variation in the three group

Atelectasis was observed in 2 cases in group I whereas there were none in group II and III and there was no observed complication in the form of barotrauma.

Discussion

In modern day surgery, laparoscopic surgery has emerged as a safe technique with a vast range of clinical applications [14]. However, pneumoperitoneum leading to increased intraabdominal pressure, changes in patient decubitus and mechanical ventilation during laparoscopy can lead to extensive adversative effect on body physiology and global haemodynamics [15-19]. Numerous rapid and safe anaesthetic approach including application of PEEP as well as open lung ventilation have been used to prevent complications arising from iatrogenic pneumoperitoneum during laparoscopy.

Historically, high tidal volume (10-15 ml/kg) during mechanical ventilation has been used to prevent hypoxemia and to prevent gradual loss of lung volume due to atelectasis.[20] Similarly lung-protective ventilation, using lower tidal volume (calculated on the predicted body weight instead of actual body weight) and PEEP, promoted by the publication of the landmark ARDS Network in 2000 [21], demonstrated reduced mortality in patients with ARDS.

The present study was designed to study the effect of PEEP on diaphragmatic functions in laparoscopic colorectal surgery patients, following the creation of pneumoperitoneum and Trendelenburg's position, using POCUS. Due to the increased abdominal pressure and cranial displacement of abdominal viscera, the diaphragmatic excursion was compromised in all three study groups but compared to group II and II where PEEP was used the excursion was significantly low in group I. It has been well documented that application of PEEP increases the functional residual capacity which is compromised due to increased intra-abdominal pressure and cranial displacement of diaphragm due to Trendelenburg's position and in turn prevents atelectasis [22, 23].

In a study done by Meininger *et al.*, on patients undergoing totally endoscopic robot assisted radical prostatectomy, the use of constant PEEP of 5 cmH_2O preserved the arterial oxygenation during prolonged pneumoperitoneum [24].

Hee Jong Lee *et al*., in their study done on 100 patients undergoing robot assisted laparoscopic radical prostatectomy observed that a PEEP of 7 cmH_2O compared to 0, 3, 5 and 10 cmH_2O was associated with greater improvement of PaO2 and alveolar-arterial difference in oxygen tension ($AaDO_2$) without instigating excessive PAP [25].

In a similar study to study effect of PEEP on diaphragmatic function of patients undergoing laparoscopic colorectal surgery, Rashwan *et al*., concluded that application of PEEP of 5 cmH_2O was helpful in preserving diaphragmatic excursion during laparoscopic colorectal surgery, and that it significantly reduced the incidence of atelectasis [26].

In 2013, role of lung ultrasonography was studied by Monastesse *et al*., on 30 patient who underwent laparoscopic surgery and USG was concluded to be a feasible investigatory option for diagnosis of atelectasis and other respiratory complications in perioperative period [27]. Although the ultrasonographic evaluation of structure and dynamic function of diaphragm is accurate and relatively easy to learn, its role is limited in patients having pre-existing pulmonary or neuromuscular disease.[28] Some studies have also restricted the interpretation and generalization of cut off values of excursion values measured by ultrasonography in heterogeneous population, as such measurement is dependent of maximal inspiratory effort of an individual [28, 29].

CONCLUSION

In the study a PEEP of 5 cmH_2O was found to be helpful in preventing atelectasis and maintaining diaphragmatic functions, without any significant increase in PIP, barotrauma when compared with identical study population undergoing laparoscopic colorectal surgery with PEEP of 10 cmH_2O or without PEEP, however larger RCTs and meta-analysis are required to validate the result.

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