Original Article

Lung Ultrasound Versus Dynamic Lung Compliance to Detect the Optimum Positive End-Expiratory Pressure After Alveolar Recruitment for Patients Undergoing Laparoscopic Gastric Sleeve Surgery: A Randomized Trial

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Abstract

Background: Various maneuvers are used to maintain oxygenation and prevent atelectasis and desaturation during general anesthesia in bariatric surgery. These maneuvers include alveolar recruitment (ARM) and positive end-expiratory pressure (PEEP). The current study aimed to illustrate the role of transthoracic lung ultrasound (LUS) as a clinical tool in comparison to dynamic lung compliance Cdyn for the detection of optimum PEEP after ARM for obese patients undergoing laparoscopic gastric sleeve surgery.

Materials and Methods: Sixty patients who were scheduled for laparoscopic gastric sleeve surgery, 18-60 years old, of both sex, American Society of Anesthesiologists physical status ASA II, and body mass index BMI>30kg/m2 were enrolled in the study. They were randomly allocated into two groups to detect the optimum PEEP after ARM, group I lung Cdyn (n=30) and group II LUS (n=30). In both groups, hemodynamic parameters HR and MAP, SpO2, PaO2, and PaO2/FiO2 were recorded. A lung ultrasound score (LUSS) was used in the US group.

Results: Both techniques effectively detected optimum PEEP after ARM without significant differences. Hemodynamics (HR, MBP) significantly changed within groups without significant differences between the groups regarding such changes. Regarding SpO_2, PaO_2, and PaO_2/FiO_2, there was a significant increase within groups, especially after ARM, without substantial differences regarding such changes. Postoperative pulmonary complications (PPCS); PaO2<80mmHg, and SpO2<94% were non-significantly more frequent in the C_{dyn} group.

Conclusion: Both lung C_{dyn} and LUS were effective methods to detect the optimum PEEP needed after ARM in laparoscopic gastric sleeve surgery.

Keywords: Dynamic lung compliance, Lung ultrasound, Alveolar recruitment maneuver

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Introduction

Obesity has emerged as a global pandemic in recent years (1). Obesity is defined as a disease due to a dysfunction of human physiology with various etiologies as genetic, environmental, and endocrinal (2). Obese patients face significantly increased risks of cardiovascular, respiratory, and renal disease as well as several neuroendocrine disorders, including diabetes mellitus type 2, dyslipidemia, hypertension, obstructive sleep apnea (OSA), and gastroesophageal reflux disease (GERD) (3).

Nowadays, bariatric surgery, particularly the laparoscopic approach, has gained popularity and is a successful long-term modality for reducing obesity and associated comorbidities (4). Unfortunately, obese patients are more likely to suffer from atelectasis after surgeries under general anesthesia due to impairment of the respiratory mechanics promoting airway closure with a reduction in oxygenation (5).

Moreover, laparoscopic surgeries may contribute further to the development of postoperative atelectasis. The effects of pneumoperitoneum and Trendelenburg position with the increased intra-abdominal pressure can lead to cranial movement of the diaphragm with subsequent compression of the basal lung areas (6, 7). Effects of pneumoperitoneum include reduced functional residual capacity FRC, vital capacity VC (8), lung atelectasis (9), decreased respiratory compliance, and increased peak airway pressure (10).

The concept of "protective ventilation" is based on three ventilator parameters, low tidal volume (TV), alveolar recruitment maneuver (ARM), and positive end-expiratory pressure (PEEP) to keep a recruited lung open during general anesthesia. Protective ventilation is responsible for the reduction of postoperative pulmonary complications (PPC_s) (11). Optimum PEEP adjustment with lung-"protective ventilation" could be a beneficial approach (12-14). It is challenging, however, to guard against atelectasis without overinflating the lungs. Variable approaches have been tried to adjust the PEEP precisely such as electrical impedance tomography or dead space-guided procedures, however, they required either specialized equipment or were prone to falsies (15, 16).

Lung ultrasonography (LUS) is a useful tool for quick and accurate diagnoses of atelectasis under general anesthesia. The main benefit of ultrasound evaluation is that it may be used repeatedly and non-invasively intraoperatively, eliminating the need to transfer the patient to the radiology department (17). The purpose of this study was to evaluate the role of transthoracic LUS as a clinical tool in comparison to lung C_{dyn} for the detection of optimum PEEP for obese patients undergoing laparoscopic gastric sleeve surgery.

Methods

This prospective, randomized clinical trial was approved by the research ethics committee of the faculty of medicine, Ain Shams University (FMASU R 127/2020), and registered at clinicaltrials.gov with ID (NCT04704596), and obtaining informed consent from all patients. Sixty patients of both sex scheduled for laparoscopic gastric sleeve surgery, BMI>30 kg/m2, ASA II, 18-60 years old, inferior vena cava collapsibility index>50% with diameter 1.5-2.5 cm calculated by ultrasound (18), and with normal preoperative lung ultrasound were enrolled in the study.

Exclusion criteria included patients who refused to participate, had abnormal preoperative lung ultrasound, had pre-existing significant pulmonary disease, history of chronic obstructive pulmonary disease COPD or emphysematous bullae, history of lung or pleural surgery, pulmonary hypertension, home oxygen therapy, and pre-existing cardiac dysfunction.

Patients were randomly allocated into two groups:

Group I C_{dyn} (*n*=30): Patients experienced ARM with optimal PEEP strategy applied with the guidance of dynamic lung compliance c_{dyn}, which was calculated automatically by the anesthesia machine (Siesta I TS, Dameca DK-2610- Denmark) on a breath-by-breath base.

GroupII LUS (*n*=30): Patients experienced ARM with optimal PEEP strategy applied with the guidance of LUS. Each lung was examined by ultrasound views B-mode display with a 3-5MHz curved transducer (TOSHIBA, Model USAP-770A, JAPAN).

Anesthetic technique

All patients were assessed preoperatively by routine evaluation on the day before surgery and were instructed about the technique of ARM. Lung ultrasonography was done for all patients just preoperatively with the exclusion of any patient with abnormal pathological findings.

In the operating theatre, an intravenous (IV) access was secured in the dominant hand, 1-2mg midazolam was given, and standard American Society of Anesthesiologists (ASA) monitoring including electrocardiogram (ECG) and pulse oximetry SpO2 was established. A radial artery catheter after local anesthesia was inserted in the non-dominant hand for invasive blood pressure (IBP) monitoring and arterial blood gas analysis (ABG_S). Baseline heart rate (HR), mean arterial pressure (MAP), and SpO2 readings were recorded. Ringer's acetate 10 mL/kg was started to be infused for all patients.

The lean body weight (LBW) derived from the James equation, defined as the mass of non-adipose tissues (maximum 100 kg in males and 70 kg in females) was used to calculate all drug doses except for neostigmine where the adjusted body weight (IBW+40% excess weight) was used with a maximum dose of 5mg (19).

After preoxygenation using O_2/Air mixture (FiO_2=0.8) for 3-5 min, general anesthesia was induced with fentanyl 1-2μg/kg, then IV propofol 1.5 - 2 mg/kg and rocuronium 0.9 mg/kg was given to mediate endotracheal intubation. End-tidal CO2 monitoring was established using capnography, and ventilation was adjusted to maintain normal end-tidal CO2. Anesthesia was maintained with sevoflurane, oxygen/air mixture (60%/40%), and rocuronium was given at 0.15 mg/kg according to the nerve stimulator. Patients were carefully shifted to the surgical position 30-degree reverse Trendenlberg position. In all patients, mechanical ventilation was started using pressure-regulated volume control mode (PRVC). Ventilator settings included a tidal volume (TV) of 6-8 ml/ kg of ideal body weight (IBW) (calculated from the patient's height and a predicted normal body mass index (BMI)) with an inspiratory/expiratory (I/E) ratio of 1:2 and a PEEP of 5 cm H_2O. The depth of anesthesia was monitored by the bispectral index (BIS), which was maintained within 40-60 by IV infusion of dexmedetomidine 0.2-0.5 μg/kg/hr and regulating the sevoflurane concentration as needed.

The technique of ARM and measuring the optimum PEEP: ARM means a sustained increase in airway pressure to open collapsed alveoli, after which the optimum PEEP value was applied to keep the lungs open.

In our study, ARM was performed directly after pneumoperitoneum. In both groups, dexmedetomidine infusion was discontinued during ARM and continued after optimum PEEP detection. Oxygenation parameters (SpO_2, PaO_2, PaO_2/FiO_2) were recorded at specific times baseline (T0), after CO2 insufflation (T1), after optimum PEEP adjustment following ARM (T2), before extubation (T3), 4h after recovery (T4).

In group I (c_{dyn}): The ARM was carried out after a switch to pressure-controlled ventilation (PCV). It consists of a stepwise increase in peak airway pressure by increasing PEEP every 2 respiratory cycles while maintaining a constant inspiratory pressure (IP) of 15 cmH2O until a peak IP 35-40cmH_2O and a PEEP of 20-25cmH_2O was reached and maintained for about 10-20 seconds, followed by a progressive reduction of the pressure until finally the optimal PEEP is reached (which correspond to 2 cmH_2O more than the PEEP that gives the first reduction of the C_{dyn} calculated by the anesthesia machine (collapse point) (20). The collapse point is the value of IP and PEEP at which dynamic lung compliance decreased abruptly. The ARM was repeated with the same steps and stabilized at the already-known optimal PEEP during the reduction of the pressures.

Finally, the patient was switched to the PRVC mode with a low TV of not more than 6-7 ml/kg of the IBW in association with the obtained optimal PEEP which was specific for each patient.

In group II (LUS): Lung ultrasonography can help to set optimum PEEP in mechanically ventilated patients undergoing bariatric surgery. The same steps for ARM were achieved with the ultrasound probe imaging the re-aeration of the collapsed lung zones. Continuous ultrasound views were taken during the step-wise decrease in inspiratory pressure until loss of lung aeration (collapse point). The optimal PEEP was detected during decreasing the pressure (which corresponds to 2 cmH_2O more than the PEEP that gives the first lung collapse; which manifests as slight to moderate loss of lung aeration from isolated to coalescent B-lines (21). (Fig 2)

Ultrasound technique: An experienced well trained blinded anesthetist performed all ultrasound scans. LUS was done at specific times, after pneumoperitoneum, during ARM for detection of optimum PEEP, after extubation, and 4h after recovery. Patients were in the supine position. Each Hemi- thorax was divided into 6 areas using 2 axial lines (one1 cm above the nipple line which was fixed by medical adhesive tape to avoid the change of nipple position during patient positioning, and the second above the diaphragm) and 3 longitudinal lines (parasternal, anterior and posterior axillary). The 12 lung areas were scanned sequentially from right to left, cranial to caudal, and anterior to posterior. According to LUS Score for consolidation and aeration, the density of B-lines was divided into 4 grades. (0) 0-2 B lines (1) ≥3 B-lines (2) multiple coalescent B-lines, and (3) consolidation. We defined atelectasis if any region had a LUSS of 2 (22).

After completion of the surgery, suction of oral secretions was done, and the effect of muscle relaxant was reversed by (atropine 0.02 mg/kg and neostigmine 0.04 mg/kg with a maximum of 5mg) after full recovery of neuromuscular function. Extubation was achieved after confirming recovery of awareness, and the T4/T1 ratio was 90%. After satisfactory recovery, Patients were transferred to the post-anesthesia care unit PACU, where a blinded observer anesthesiologist recorded any PPC_S. 4 hours postoperatively LUS was done.

The primary outcome was the mean PaO_2 and other ABG measurements after optimum PEEP detection in both groups, whereas the secondary outcomes were the changes in hemodynamic parameters, oxygenation parameters, and the incidence of PPC_S.

Sample size calculation: The required sample size was calculated using G*Power software version 3.1.0. The primary objective of the current study was to compare the mean PaO_2 and other ABG measurements after optimum PEEP adjustment between the two study groups. Assuming a type I error of 0.05 and 80% power, a sample size of 30 cases in each group will be needed to detect an effect size (d) of 0.8 in the primary outcome of interest, taking into account the 20% dropout rate.

Statistical analysis: Data management and analysis were done using IBM SPSS statistics (Statistical Package for Social Sciences) software version 22.0, IBM Corp., Chicago, USA, 2013. Quantitative normally distributed variables described as mean±SD (standard deviation) were then compared using an independent t-test for non-repeated variables and repeated measure analysis of variance (RMANOVA) for repeated variables after testing for normality using the Shapiro-Wilk test. Qualitative variables are described as numbers and percentages and compared using the Chi-square test and Fisher's Exact test for variables with small expected numbers. The level of significance taken at P value < 0.050 was significant, otherwise was non-significant.

Results

A total number of 63 patients were recruited for the study, 3 patients were excluded, 1 patient refused to participate, and 2 patients did not meet the inclusion criteria. Finally, 60 patients completed the study. The selected 60 patients were divided into two equal groups (30 patients in each group) (Fig. 1).

The demographic data, including (Age, BMI, ASA, gender), type and duration of surgery, time of pneumoperitoneum, and inferior vena cava (IVC) collapsibility index and diameter, were not statistically different in the two groups (Table 1).

Hemodynamic parameters (MAP, HR) initially increased after intubation, then decreased gradually below the baseline level from insufflation until Exsufflation, then re-increased to approach baseline at extubation. Hemodynamics significantly changed within groups without significant differences between the groups regarding such changes (Table 2).

Regarding oxygenation parameters, Spo2 increased significantly in both groups at (T1, T2, T3, and T4) in comparison to T0 with a P<0.001, especially after ARM (Spo2 at T2 was 98.6±0.5 in the C_{dyn} group and 98.4±0.5 in LUS group).

Regarding PaO_2, compared to baseline (PaO_2 was 85.8±1.6 mmHg in C_{dyn} and 85.5±1.9 mmHg in the LUS group respectively.) there was a significant

Table 1: Comparison of demographic data and baseline characteristics

Variables		**Group I C_{dyn} (N=30)**	**Group II LUS (N=30)**	**P-value**
Age (years), Mean±SD		37.2±6.6	35.9±6.6	^0.437
BMI (kg/m^2), Mean±SD		37.6±3.6	38.5±4.8	^0.413
Gender, (n, %)	**Male**	13 (43.3%)	14 (46.7%)	#0.795
	Female	17 (56.7%)	16 (53.3%)	
ASA, (n, %)	**II**	30(100%)	30(100%)	-------
Surgery type, (n, %)	**Sleeve gastrectomy**	22 (73.3%)	24 (80.0%)	#0.542
	Sleeve gastrectomy+gastric bypass	8 (26.7%)	6 (20.0%)	
Pneumoperitoneum (min), Mean±SD		85.1±4.8	84.7±5.7	^0.807
Surgery duration (min), Mean±SD		132.0±5.3	133.8±6.3	^0.219
IVC diameter (cm), Mean±SD		2.0±0.3	1.9±0.2	^0.230

^Independent t-test. #Chi square test.

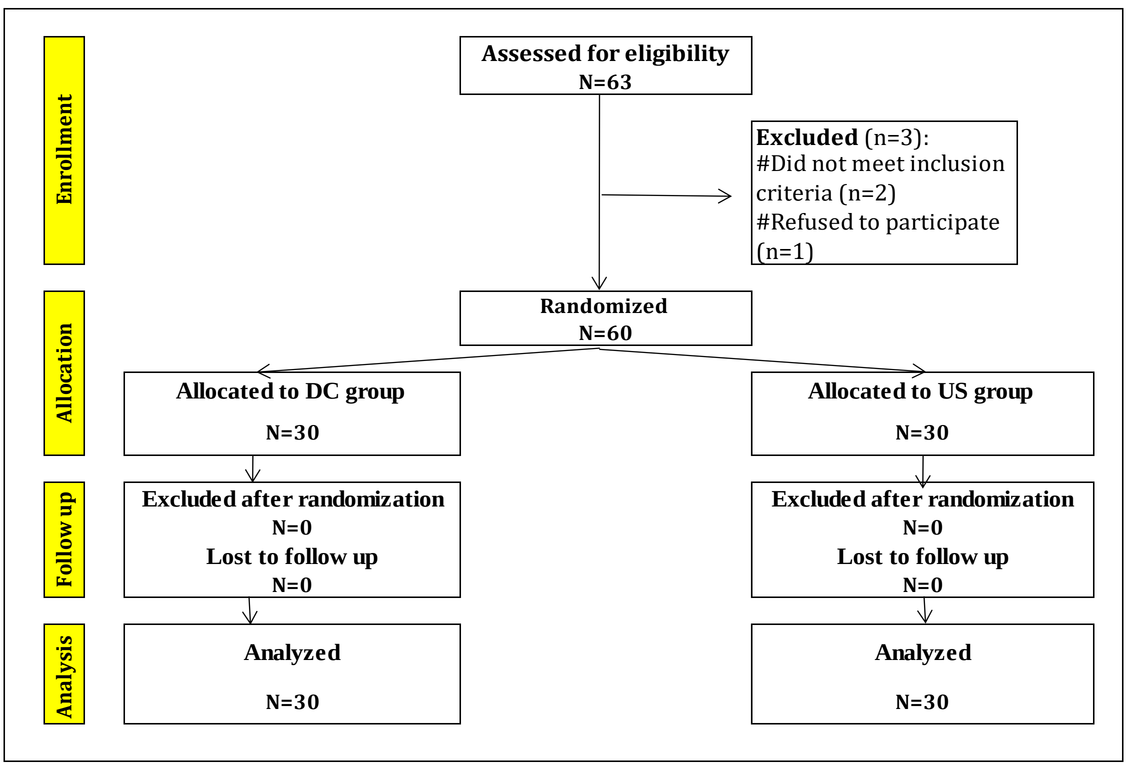

Figure 1. CONSORT patient flowchart.

increase, especially after ARM and optimum PEEP detection to reach a maximum value at T3 (PaO_2 was

Table 2: Hemodynamics among the studied groups

Time	GroupI C_{dyn} (N=30)	GroupII LUS (N=30)	Effect size (C_{dyn} relative to the US)	
			Mean±SE	95% CI
Mean blood pressure (mmHg), Mean±SD				
Baseline	102.5±4.7	101.6±5.1	0.9±1.3	-1.6–3.4
After intubation	111.3±4.2	110.9±4.4	0.4±1.1	-1.8–2.6
After CO_2 insufflation	93.9±2.9	93.8±3.1	0.1±0.8	-1.4–1.7
After adjustment of optimum PEEP	75.8±2.4	74.4±3.2	1.4±0.7	-0.1–2.8
AfterCO_2 exsufflation	75.5±3.1	75.2±3.2	0.3±0.8	-1.3–1.9
After extubation	94.4±2.2	94.3±2.2	0.2±0.6	-1.0–1.3
¤P-values	Between groups 0.425	Within groups **<0.001***	Interaction 0.495	
Heart rate (beat/minute), Mean±SD				
Baseline	79.2±1.6	78.8±2.0	0.4±0.5	-0.6–1.3
After intubation	96.5±1.7	96.3±1.9	0.2±0.5	-0.7–1.1
After CO_2 insufflation	74.9±1.9	74.6±2.1	0.4±0.5	-0.7–1.4
After adjustment of optimum PEEP	72.1±1.8	71.1±2.4	1.0±0.5	-0.1–2.1
AfterCO_2 exsufflation	73.3±1.8	73.1±1.7	0.1±0.5	-0.8–1.0
After extubation	84.1±2.5	83.9±2.9	0.2±0.7	-1.2–1.6
¤P-values	Between groups 0.379	Within groups <0.001*	Interaction 0.406	

¤RMANOVA. SE: Standard Error. CI: Confidence interval. *Significant.

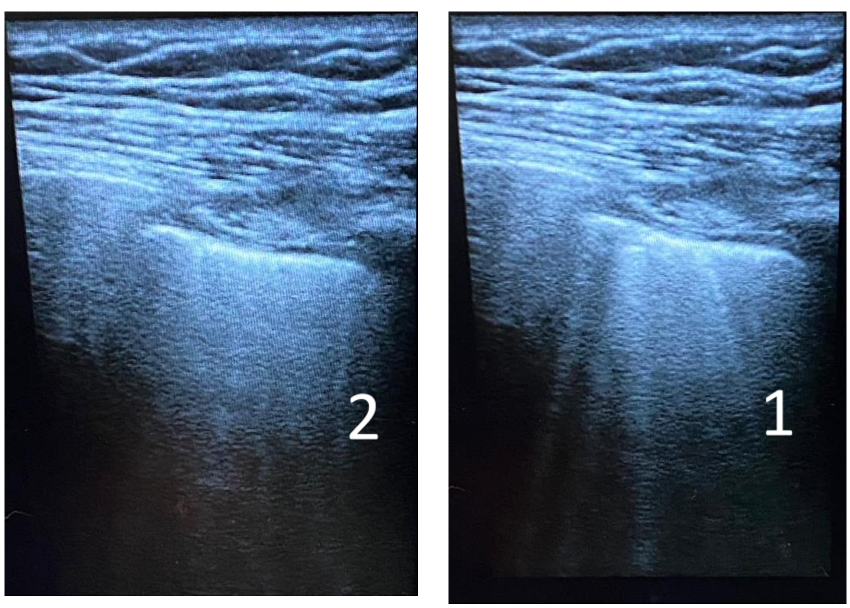

Figure 2. LUS after pneumoperitoneum with B lines (1) LUS after optimum PEEP adjustment following ARM (2).

282.1±6.5 mmHg in Cdyn group and 281.0±7.2 mmHg in LUS group). PaO_2 decreased to reach the baseline

Table 3: Comparison of oxygenation parameters

Time	GroupI C_{dyn} (N=30)	GroupII LUS (N=30)	Effect size (C_{dyn} relative to LUS)	
			Mean±SE	**95% CI**
SpO_2 (%), Mean±SD				
T-0	96.6±0.5	96.5±0.5	0.2±0.1	-0.1–0.4
T-1	97.6±0.5	97.5±0.5	0.1±0.1	-0.1–0.4
T-2	98.6±0.5	98.4±0.5	0.2±0.1	-0.1–0.4
T-3	98.6±0.5	98.4±0.5	0.2±0.1	-0.1–0.5
T-4	98.0±2.1	98.3±1.3	-0.3±0.4	-1.2–0.6
¤P-values	Between roups 0.648	Within groups **<0.001***	Interaction 0.271	
PaO_2, Mean±SD				
T-0	85.8±1.6	85.5±1.9	0.3±0.5	-0.6–1.2
T-1	141.7±4.2	140.9±4.3	0.8±1.1	-1.4–3.0
T-2	255.0±1.9	254.7±2.0	0.3±0.5	-0.7–1.3
T-3	282.1±6.5	281.0±7.2	1.2±1.8	-2.4–4.7
T-4	86.8±1.9	86.2±2.4	0.6±0.6	-0.5–1.7
¤P-values	Between roups 0.407	Within groups **<0.001***	Interaction 0.674	
PaO_2/FiO_2, Mean±SD				
T-0	406.1±23.5	405.8±26.0	0.3±6.4	-12.5–13.1
T-1	283.3±8.3	281.7±8.7	1.6±2.2	-2.8–6.0
T-2	510.0±3.8	509.3±4.0	0.7±1.0	-1.3–2.7
T-3	564.3±13.1	561.9±14.4	2.3±3.6	-4.8–9.4
T-4	173.5±3.9	172.3±4.8	1.2±1.1	-1.0–3.4
¤P-values	Between roups 0.522	Within groups **<0.001***	Interaction 0.850	
Postoperative Complications				
			Relative risk	**95% CI**
PPC_S (SO_2<94%) and (PO_2<80%)	3 (10.0%)	1 (3.3%)	3.00	0.33–27.23
§P-value	§0.612			

¤RMANOVA. §Fisher's Exact test. SE: Standard error. CI: Confidence interval.

values at T4 in both groups.

Regarding PaO_2/FiO_2 there was a significant decrease in both groups after CO2 insufflation followed by a significant increase after ARM and optimum PEEP adjustment and finally decreased to reach below the baseline levels after extubation. PPC_S (PaO_2<80mmhg, SpO_2 <94% were non-significantly more frequent in the C_{dyn} group (Table 3).

Regarding the value of the detected optimum PEEP, there was no significant difference between the studied groups. In group I C_{dyn}, it was 10.3±0.6 cm H2O while it was 10.5±0.6 cm H2O LUS group II.

Discussion

This study demonstrated that applying either LUS or C_{dyc} was effective in optimum PEEP detection after ARM in morbidly obese patients undergoing gastric sleeve surgery. Oxygenation parameters Spo2 and PaO_2 improved after adjustment of optimum PEEP in the ventilation parameters in both groups.

Many ventilator strategies were found to improve gas exchange in morbidly obese patients undergoing bariatric surgery. Lung atelectasis is commonly present after induction of general anesthesia. ARM is the most effective strategy to reinflate atelectatic lung zones and improve intraoperative PaO_2 and SpO2 in patients undergoing bariatric surgery. ARM is performed using high, sustained PEEP to increase end-expiratory lung volume and reopen atelectatic lung areas (23).

In our study, we selected PRVC as a basic ventilation mode that allows for breath-by-breath pressure adjustments to provide the desired volumes in the face of changing respiratory resistance and lung compliance. PRVC mode provides the benefits of variable flow from Pressure control with the guaranteed minute ventilation of volume control without requiring the need to adjust the inspiratory pressure. In PRVC mode, higher respiratory resistance or worsening lung compliance causes the ventilator to increase the inspiratory pressure to achieve the preset TV (24).

To the best of our knowledge, in the present study, we applied the ARM strategy to adjust the optimum PEEP by two different methods, C_{dyn} guided optimum PEEP detection or LUS-guided optimum PEEP detection. In our study, we preferred only two interventional groups without the involvement of a control group to allow the maximum ventilatory management and benefit for patients included in the study.

In our study, we selected the dynamic lung compliance C_{dyn} not the static lung compliance as C_{dyn} not only reflects the lung and chest wall distensibility but also it reflects airway resistance. C_{dyn} decreases when there is an increase in either lung stiffness or airway resistance. C_{dyn} can be calculated from the following equation:

$C_{dyn} = V_t\,(P_{pk}\text{- PEEP})$, where V_t is tidal volume, P_{pk} is peak airway pressure, and PEEP is positive end-expiratory pressure (25).

In both groups, we found that using C_{dyn} or LUS-guided optimum PEEP adjustment mediated an improvement in the intraoperative SpO2, PaO_2, and P/F ratio in patients undergoing laparoscopic gastric sleeve surgeries. PPC_S as hypoxia and atelectasis were also reduced. Optimum PEEP adjustment is essential to prevent PPC_S without significant hemodynamic instability.

Whalen et al. researched the effect of ARM on PaO_2 in patients scheduled for laparoscopic bariatric surgery. They concluded that the ARM strategy is very effective in improving intraoperative PaO_2 (26). Another study done by Hesham et al explained that intraoperative ARM then PEEP 10 cm H2O were effective in reducing lung atelectasis, better oxygenation, shorter PACU stays, and fewer PPC_S (27).

Futier E et al. compared the protective ventilation strategy TV 6–8 mL/kg IBW, PEEP 6–8 cmH2O, ARM every 30 min to a traditional strategy TV 10–12 mL/kg IBW without PEEP or ARM in abdominal surgery. "Protective ventilation" decreased PPCS and the length of hospital stay (28).

In agreement with our results, Halawa et al. found that prophylactic use of ARM with stepwise optimum PEEP approach C_{dyn} guided was accompanied by a reduction in PPC in hepatic recipients (29). Another study done by Nakahira et al assessed the effect of ARM on respiratory resistance under general anesthesia, the investigators found a beneficial effect of ARM in reducing respiratory resistance and improving pulmonary compliance (30).

Regarding lung ultrasound score LUSS, Kim et al. found that higher LUSS with a subsequent higher degree of atelectasis was noticed when ARM was done with a high FiO_2 (1.0) than with a low FiO_2 (0.4) (31).

In agreement with our results, Elshazly et al. demonstrated the use of LUS to detect the optimum PEEP can improve oxygenation with subsequent reduction of PPCS in laparoscopic bariatric surgeries (32).

Another study done by Monastesse et al demonstrated the feasibility of using LUS during all phases of the perioperative period and its ability to detect and track both lung atelectasis and respiratory complications. Also, The LUS was able to evaluate intraoperative aeration loss which was correlated with oxygenation changes (33). Our results are compatible with those of Monastesse et al, we observed a reduction in lung aeration after pneumoperitoneum (Fig.2), and in our study lung re-aeration, was found after ARM and adjustment of optimum PEEP.

Limitations of the study: The current study had some limitations. First, our study included only patients scheduled for laparoscopic gastric sleeve surgery only where patients were in the reverse Trendenlberg position, our study did not involve other types of surgeries as well as other surgical positions. Second, our study did not involve a control group with fixed predetermined PEEP, we suggested that optimum PEEP is variable and specific for every patient. Third, C_{dyn} optimum PEEP adjustment can be only done in mechanically ventilated patients, also not all anesthesia machines involve the software for calculating and showing C_{dyn} breath by breath. Finally, both techniques did not assess lung hyperinflation. Although complications related to PEEP-induced hyperinflation were not present in our patients because we used lung-protective ventilation with relatively low TV.

Conclusion

Both lung C_{dyn} and LUS were effective methods to detect the optimum PEEP needed after ARM in laparoscopic gastric sleeve surgery. Lung C_{dyn}-guided optimum PEEP is patient-specific and apparatus-dependent, while LUS has an objective score.

Acknowledgment

None.

Conflicts of Interest

The authors declare that they have no conflict of interest.

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