

Comparative Study between Intra-operative Ventilatory Techniques to Prevent Postoperative Pulmonary Complications in Obese Patients Undergoing Laparoscopic Surgery

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ABSTRACT

Background: Managing ventilation and oxygenation during laparoscopic procedures in morbidly obese patients undergoing surgery represents many challenges. There is no specific guideline on the ventilation modes for this group of patients. Although several studies have been performed to determine the optimal ventilatory settings for those patients, the answer is yet to be found. The aim of this study was to determine which mode of ventilation is more effective in improvement of intraoperative oxygenation and prevention of postoperative pulmonary atelectasis with its consequences is PEEP 10cmH₂O alone is effective or Recruitment maneuver followed by PEEP 10 cmH₂O has better results. **Aim of the Work:** The study will be performed to compare different intra-operative ventilatory techniques that prevent early postoperative pulmonary complications especially atelectasis in obese patients undergoing laparoscopic surgery. **Patients and Methods:** This prospective, interventional, therapeutic, randomized clinical study was conducted at Ain Shams University Hospitals, operating theatre department on 100 morbidly obese adult patients of ASA physical status II, admitted to Ain Shams university hospital, scheduled for elective laparoscopic surgery either bariatric or non bariatric. The study was carried out after approval of the departmental ethical committee. The patients were subdivided into 4 groups A, B, C and D, (25) patients for each group. **Results:** Regarding the value of PO₂/ Fi O₂, there is no statistically significant difference between all groups in the preoperative and intra operative values. But there is statistically significant increase in group D and group C respectively compared to group A and B in both post operative and 6 hours post operative values. Regarding CT chest, Group A showed the highest number of both lobar and segmental atelectasis followed by group B which showed also a high number of segmental atelectasis. In despite, group C showed a higher number of plate and lamellar atelectasis followed by group D that showed a high number of lamellar atelectasis but the lowest number of other atelectasis scores. **Conclusion:** In conclusion, repeated Recruitment Maneuvers combined with 10 cmH₂O of PEEP have beneficial effects on oxygenation continued into the early recovery period and decrease pulmonary complications in the early post operative period in morbid obese patients undergoing laparoscopic surgery. **Recommendations:** Further studies on a larger scale of patients are needed to confirm the results obtained by this work.

Keywords: intraoperative ventilatory, pulmonary, obese, laparoscopic surgery.

INTRODUCTION

The number of obese patients undergoing surgery is increasing, the pathophysiological changes induced by obesity make these patients prone to peri-operative complications especially pulmonary complications which are the main cause of overall peri-operative morbidity and mortality following general anesthesia. Pulmonary complications include atelectasis, carbon dioxide retention and pneumonia, these complications may extend to the postoperative period leading to delay discharge from post anesthesia care unit, increase the need for respiratory physiotherapy or non-invasive ventilation and also increase the probability of intensive care unit admission. Prevention of these complications would improve the quality of medical care, decrease hospital stay and costs⁽¹⁾. Reduction in peri-operative morbidity is the major advantage of laparoscopic surgery, as it

preserves pulmonary function when compared to open surgery, laparoscopic surgery also decreases cardiac and wound complications and reduces organ-system impairment, the hypermetabolic stress response of surgery that lead to increase myocardial O₂ demand, energy expenditure, pulmonary work load and renal work load, is also attenuated in laparoscopic surgery as the magnitude of this stress response is directly related to the magnitude of tissue injury⁽²⁾.

Obese patients are more prone to develop pulmonary atelectasis due to decreased chest wall and lung compliance, and decreased functional residual capacity with impairment of pulmonary gas exchange and subsequent hypoxia, These changes often occur after induction of general anesthesia and may persist for 24 hours (hr) post operatively, the degree of hypoxemia is directly related to Body Mass Index (BMI)⁽³⁾.

Different strategies have been investigated to re-expand collapsed lung during general anesthesia to optimize oxygenation and to improve respiratory mechanics. The positive end expiratory pressure PEEP has been shown to counterbalance the diaphragm cranial shift increasing functional residual capacity and decreasing respiratory system elastance⁽⁴⁾.

The other strategy is recruitment maneuver which is performed by the anesthetist by inflating the patient's lungs to an airway pressure of 40 cmH₂O, this increased air way pressure must be maintained for duration of 7-8 seconds, this maneuver is used to increase the patient's lung volumes and restore their pulmonary function to a pre-anesthetic state⁽⁵⁾. In laparoscopic surgery, the recruitment maneuver should be done 15 minutes after pneumoperitoneum as its effect may be lost after pneumoperitoneum, which necessitates a further recruitment maneuver to keep the alveoli opened⁽⁶⁾.

AIM OF THE WORK

The study will be performed to compare different intra-operative ventilatory techniques that prevent early postoperative pulmonary complications especially atelectasis in obese patients undergoing laparoscopic surgery.

PATIENTS AND METHODS

After approval of the departmental ethical committee, this Prospective, Interventional, Therapeutic, Randomized clinical study was conducted at Ain Shams University Hospitals, operating theatre department on 100 morbidly obese adult patients of ASA physical status II, admitted to Ain Shams university hospital, scheduled for elective laparoscopic surgery either bariatric or non bariatric. The patients were subdivided into 4 groups A, B, C and D, (25 patients for each group).

Inclusion criteria

- 1- Morbid obese patients of both sexes
- 2- BMI ranging from 35-50 kg/m²
- 3- Aging between 20-60 years old
- 4- Scheduled for elective laparoscopic surgery either bariatric or non bariatric
- 5- ASA physical status II.

Exclusion criteria

- 1- Patient refusal
- 2- Patients were hospitalized more than 24 hrs before surgery to avoid the risk of hospital acquired chest infection.
- 3- Patients with ASA status III, IV
- 4- Obese Patients with BMI > 50 kg / m² as CT chest could not be done for patients with BMI more than 50 kg / m².

- 5- Any complications occurred that necessitated laparotomy

Patient groups

Group (A): The patients received volume controlled ventilation (VCV) with PEEP 10cm H₂O.

Group (B): The patients received pressure controlled ventilation (PCV) with PEEP 10cm H₂O.

Group (C): The patients received volume controlled ventilation (VCV) with Recruitment Maneuver (RM) and PEEP 10 cm H₂O was added.

Group (D): The patients received pressure controlled ventilation (PCV) with Recruitment Maneuver (RM) and PEEP 10 cm H₂O was added.

Methodology

1-Preoperative assessment:

Routine pre-operative assessment was done to all patients including: history of patient's medical condition as cardiac, chest, hepatic or renal problems. clinical examination including the vital data and air way assessment. laboratory investigations as (complete blood picture, liver function tests, kidney function tests, prothrombin time and partial thromboplastin time), electrocardiogram (and echocardiography if ordered by the cardiologist), pulmonary function tests, blood gases and preoperative CT chest. Other investigations were done according to the medical condition.

2-Intraoperative Management

The following were carried out:

Patient preparation:

Patients were visited preoperatively in order to take history, perform clinical examination, review investigations and to start a well established doctor patient relationship.

Patients included in the study fasted for at least 8 hrs before induction of anesthesia and a peripheral venous access was secured and a baseline arterial blood sample was drawn for arterial blood gas (ABG) analysis.

Monitoring:

For all patients monitoring was started before induction of anesthesia, monitors applied were:

- 5 leads ECG to monitor heart rate and rhythm.
- Pulse oximetry to monitor oxygen saturation.
- Non invasive blood pressure monitoring with a large cuff suitable for morbidly obese patients.
- Capnography to monitor the end tidal CO₂
- Neuromuscular monitoring using the Train Of Four (TOF)

Induction of Anesthesia

A standard protocol for general anesthesia with endotracheal intubation and controlled ventilation was conducted in all patients, where

all patients received intravenous injection of ranitidine 50 mg and metoclopramide 10 mg pre-operatively, and an injection of fentanyl 2 mcg/kg (TBW) 5 min before induction. After proper pre-oxygenation by administration of O₂ by face mask (100% O₂) for 3-5 min, anesthesia was induced with injection of Propofol 2 mg/kg (TBW). The trachea was intubated with a cuffed endotracheal tube of appropriate size after achieving adequate relaxation with injection of Rocuronium 0.6mg/kg. The lungs were ventilated with 60% oxygen: 40% air and isoflurane 1.2%. Muscle relaxation was maintained with injection of rocuronium 0.2 mg/kg (TBW) every 30 minutes to maintain muscle relaxation.

To start, patients were randomized with the help of a computer-generated random number list to receive the selected mode of ventilation.

Ventilation was done according to the patient's group with adjustment of the breathing rate to maintain end tidal carbon dioxide partial pressure between 32-35 mm Hg. Carbon dioxide was insufflated into the peritoneal cavity until the intra-abdominal pressure reached 11-15mm Hg and was maintained throughout the procedure.

Group A: VCV followed by PEEP 10 cmH₂O.

Ventilation was continued with a tidal volume of 6-8 mL/kg based on lean body weight (LBW) and the respiratory rate was adjusted to maintain EtCO₂ between 32 and 35mmHg, After pneumoperitonium, PEEP 10 cm Hg was added till the end of the operation.

Group B: PCV followed by PEEP 10 cmH₂O.

The airway pressure not exceeding 30 cmH₂O was set to provide a tidal volume of 6-8 mL/kg (LBW). Respiratory rate was adjusted to keep an EtCO₂ of 32–35mmHg. then, After pneumoperitonium, PEEP 10 cmHg was added till the end of the operation.

Group C: VCV with RM followed by PEEP 10 cmH₂O.

Ventilation was continued with a tidal volume of 6-8 mL/kg (LBW) and the respiratory rate was adjusted to maintain EtCO₂ between 32 and 35mmHg, 15 min after pneumoperitonium, Recruitment maneuver was done by “bag squeezing” using the air pressure- limiting valve of the anesthesia machine to make the inspiratory plateau pressure as high as 40 cmH₂O for 15 seconds followed by PEEP 10 cmHg which was continued till the end of the operation, then Recruitment Maneuver was repeated after another 10 min using the same technique.

Group D: PCV with RM followed by PEEP 10 cmH₂O.

The airway pressure not exceeding 30 cmH₂O was set to provide a tidal volume of 6-8 mL/kg (LBW). Respiratory rate was adjusted to keep an EtCO₂ of 32–35mmHg. Then, 15 min after pneumoperitonium, Recruitment maneuver was done by “bag squeezing” using the air pressure-limiting valve of the anesthesia machine to make the inspiratory plateau pressure as high as 40 cmH₂O for 15 seconds followed by PEEP 10 cmHg which was continued till the end of the operation, then Recruitment Maneuver was repeated after another 10 min using the same technique. Crystalloid solution was given according to the calculated deficit and maintenance for every patient all through the operation. Intra-operative hypotension (decrease in MAP > 25% of base line) was treated with a bolus of normal saline 0.9% 250 ml and /or incremental dose of ephedrine 6 mg.

Emergence from Anesthesia

At the end of the surgery, Isoflurane was discontinued, muscle relaxation was reversed by neostigmine 0.05 mg/ kg and 0.015 mg/kg atropine sulphate. Tracheal extubation was performed in semi sitting position after reaching satisfactory criteria for extubation.

These criteria were as follows:

1. Intact neurological status, fully awake and alert, head lift >5 s.
2. Hemodynamically stable.
3. Normothermia, core temperature >36°C.
4. Full reversal of neuromuscular blocking drugs.
5. Respiratory rate >10 and < 30 breaths/min.
6. Baseline peripheral oxygenation SpO₂>95%.
7. Acceptable pain control in the postanesthesia care unit (PACU).

patients were kept at head-up tilt of 30°–45° To prevent development of immediate post extubation hypoxia, uninterrupted administration of oxygen was continued until patients were transferred to PACU. The patients was transferred to the PACU in the semi sitting position with supplementation of oxygen by venturi face mask(40%) with good post operative analgesia using Pethidine 50 mg bolus on demand. A non rebreathing oxygen mask was applied when oxygen saturation decreased to <92%. then the patient was transferred to post operative ICU for monitoring of the respiratory parameters.

Measurements

I- Hemodynamics

Heart rate, non invasive MAP, oxygen saturation were measured all through the operation and were recorded at the following times:

- At baseline before induction of anesthesia
- 5 min after intubation

- after establishing pneumoperitoneum
- 15 min after pneumoperitoneum
- 30 min after pneumoperitoneum(after RM)
- After another 30 min
- At the end of the procedure
- Immediately after PACU admission
- Before discharge from PACU

II- Arterial blood gas samples

was taken pre-operatively as baseline value just before induction of anesthesia, intra-operative one was taken 30 min after pneumoperitoneum and post operatively at PACU then after 6 hrs post operatively to measure partial pressure of oxygen (Pa O₂) and to calculate the ratio between PaO₂/ Fi O₂.

The need for non rebreathing O₂ mask or re-intubation was recorded.

III- Computed Topographic Imaging (CT):

CT imaging was performed pre-operatively and 6 hrs post operatively, the CT images was specifically evaluated for atelectasis. CT scans were interpreted by radiologists who were aware of the experimental protocol but unaware of patient group assignment. Atelectasis was evaluated using a Siemens Volume Zoom CT Scanner (Siemens Volume Zoom CT Scanner, Erlangen, Germany), which is classified into 4 types depending on thickness: lamellar atelectasis (<3mm), plate atelectasis (3-10mm), segmental atelectasis (>10mm but less than a lobe), and lobar atelectasis (atelectasis involving the entire lower lobe). Primary end points include the results of arterial blood gases and (CT) chest.

End points:

The study time bound was till (6) hours postoperatively, but it was aborted in the following cases:

- In case of intra-operative persistent hypotension (decrease MAP >25%) of base line
- In case of intra-operative change of the mode of ventilation due to any ventilatory problem.

The study was approved by the Ethics Board of Ain Shams University.

RESULTS

Statistical presentation and analysis of the present study was conducted, using the mean, standard Deviation, analysis of variance [ANOVA] test and chi-square tests by *SPSS V. 20*.

$$\text{Mean} = \frac{\sum x}{n}$$

Where \sum = sum & n = number of observations.

Standard Deviation [SD]:

$$SD = \sqrt{\frac{\sum |x - \bar{x}|^2}{n-1}}$$

Analysis of variance [ANOVA] tests.

According to the computer program SPSS for Windows. ANOVA test was used for comparison among different times in the same group in quantitative data.

Chi-square

The hypothesis that the row and column variables are independent, without indicating strength or direction of the relationship. Pearson chi-square and likelihood-ratio chi-square. Fisher's exact test and Yates' corrected chi-square are computed for 2x2 tables.

Significant level: Non Significant >0.05

Significant <0.05* High Significant <0.001**

Patients were randomized into four groups of 25 patients according to the ventilation mode:

- **Group A (25 patients):** Patients in group A received volume controlled ventilation and PEEP 10 cm H₂O.
- **Group B (25patients):** Patients in group B received pressure controlled ventilation and PEEP 10 cm H₂O.
- **Group C (25patients):** Patients in group C received Volume controlled ventilation, RM and PEEP 10 cm H₂O.
- **Group D (25patients):** Patients in group D received Pressure controlled ventilation, RM and PEEP 10 cm H₂O.

The results showed that Patients' characteristics as regard age, sex, weight, height, BMI and the patients in all groups are ASA II, showed no statistically significant differences between the four groups as shown in table (1).

Table (1): Patients' characteristics

		Group A (n=25)	Group B (n=25)	Group C (n=25)	Group D (n=25)	Tests	
						F or X ²	P-value
Age	Mean±SD	48.57±3.56	47.89±4.08	46.31±3.69	48.07±3.57	1.713	0.169
Sex	Female	14(56%)	17(68%)	12(48%)	11(44%)	3.382	0.336
	Male	11(44%)	8(32%)	13(52%)	14(56%)		
Weight (kg)	Mean±SD	92.45±4.9	94.78±5.27	95.28±4.19	94.5±3.99	1.816	0.149
Height (cm)	Mean±SD	170.71±5.78	172.95±3.51	169.37±4.38	171.27±6.28	2.106	0.104
BMI	Mean±SD	44.67±2.09	45.01±2.18	44.16±2.47	43.86±3.06	1.073	0.364

Values are presentsd as mean ± Sd or number (%)

I-Hemodynamics**Heart rate (HR):****Table (2):** Comparison of Heart rate values in beat/min between the 4 groups which presented as mean \pm SD.

HR	Group A (n=25)	Group B (n=25)	Group C (n=25)	Group D (n=25)	ANOVA	
					f	P-value
At baseline	84.86 \pm 4.35	82.37 \pm 6.53	83.58 \pm 4.32	84.97 \pm 6.56	1.217	0.308
5min after intubation	82.47 \pm 4.58	83.65 \pm 5.43	82.33 \pm 3.79	84.96 \pm 3.94	1.866	0.141
After pneumoperitonium	85.23 \pm 6.12	84.14 \pm 5.97	86.48 \pm 5.16	86.97 \pm 5.25	1.277	0.287
15 min after pneumoperitoneum	86.12 \pm 5.85	85.15 \pm 5.24	86.54 \pm 4.57	87.39 \pm 3.71	0.900	0.444
30 min after pneumoperitoneum (after RM)	84.76 \pm 3.83	83.08 \pm 3.62	85.40 \pm 4.72	86.16 \pm 3.94	2.623	0.060
After another 30 min	83.38 \pm 4.80	82.73 \pm 6.02	83.56 \pm 4.09	85.00 \pm 4.25	0.974	0.408
At the end	84.38 \pm 4.45	85.66 \pm 6.59	86.30 \pm 3.80	86.07 \pm 5.64	0.671	0.572
PACU	82.50 \pm 4.78	83.65 \pm 5.34	84.69 \pm 4.13	83.22 \pm 5.40	0.859	0.465
Discharge from PACU	83.48 \pm 5.40	85.03 \pm 4.56	85.07 \pm 4.12	84.68 \pm 4.62	0.627	0.599

Regarding heart rate, the results showed no statistically significant difference between all groups at baseline, 5 min after intubation, after pneumoperitoneum, 15 min after pneumoperitoneum, 30 min after pneumoperitoneum (after RM), after another 30 min, at the end of the procedure, at PACU and before discharge from PACU as shown in table (3).

Mean arterial pressure (MAP):**Table (3):** Comparison of Mean arterial pressure values in mmHg between the 4 groups which presented as mean \pm SD

MAP	Group A (n=25)	Group B (n=25)	Group C (n=25)	Group D (n=25)	ANOVA	
					f	P-value
At baseline	78.31 \pm 4.68	81.39 \pm 3.87	80.09 \pm 6.31	79.95 \pm 4.78	1.601	0.194
5min after intubation	80.46 \pm 4.50	82.17 \pm 5.57	81.58 \pm 5.70	80.45 \pm 5.70	0.628	0.599
After pneumoperitonium	78.04 \pm 5.84	78.72 \pm 6.11	80.00 \pm 5.83	79.15 \pm 4.39	0.540	0.656
15 min after pneumoperitoneum	78.24 \pm 6.04	78.57 \pm 6.20	79.57 \pm 4.91	78.55 \pm 6.34	0.240	0.868
30 min after pneumoperitoneum (after RM)	79.19 \pm 6.12	82.58 \pm 5.77	78.83 \pm 6.37	78.40 \pm 6.81	2.323	0.084
After another 30 min	80.17 \pm 5.61	79.28 \pm 5.27	82.49 \pm 6.19	81.82 \pm 5.59	1.689	0.175
At the end	82.77 \pm 3.61	83.52 \pm 3.61	81.73 \pm 5.97	80.42 \pm 6.25	1.794	0.153
PACU	82.02 \pm 5.78	82.12 \pm 5.81	80.67 \pm 5.61	79.81 \pm 6.48	0.883	0.453
Discharge from PACU	81.49 \pm 6.46	79.66 \pm 5.57	82.53 \pm 4.66	80.39 \pm 4.55	1.374	0.255

Regarding mean arterial pressure, the results showed no statistically significant difference between all groups at baseline, 5 min after intubation, after pneumoperitoneum, 15 min after pneumoperitoneum, 30 min after pneumoperitoneum (after RM), after another 30 min, at the end of the procedure, at PACU and before discharge from PACU as shown in table (3).

Oxygen Saturation**Table (4):** Showing comparison of Oxygen saturation values between the 4 groups which presented as mean \pm SD.

O2 sat	Group A (n=25)	Group B (n=25)	Group C (n=25)	Group D (n=25)	ANOVA	
					f	P-value
At baseline	92.85 \pm 5.39	93.44 \pm 5.46	92.41 \pm 5.58	94.49 \pm 3.94	0.768	0.515
5min after intubation	92.72 \pm 6.43	95.80 \pm 6.06	92.64 \pm 6.76	93.13 \pm 4.55	1.558	0.204
After pneumoperitonium	93.97 \pm 5.86	93.36 \pm 6.03	94.15 \pm 6.22	92.39 \pm 5.43	0.454	0.715
15 min after pneumoperitonium	94.40 \pm 4.03	95.61 \pm 4.94	93.77 \pm 3.74	92.26 \pm 6.52	2.001	0.119
30 min afterpneumoperitonium (after RM)	94.0 \pm 4.01	93.00 \pm 4.35	96.73 \pm 6.14	95.88 \pm 6.60	2.503	0.064
After another30 min	95.41 \pm 5.08	94.84 \pm 4.76	94.81 \pm 3.63	94.97 \pm 4.23	0.097	0.962
At the end	95.70 \pm 4.90	94.30 \pm 6.17	93.91 \pm 4.71	93.65 \pm 5.43	0.733	0.535
PACU	95.10 \pm 4.83	93.81 \pm 4.29	92.91 \pm 6.48	94.12 \pm 4.06	0.814	0.489
Discharge from PACU	94.52 \pm 5.22	96.19 \pm 4.76	94.35 \pm 5.42	93.61 \pm 4.79	1.160	0.329

Regarding Oxygen saturation, the results showed no statistically significant difference between all groups at baseline, 5 min after intubation, after pneumoperitonium, 15 min after pneumoperitonium, 30 min after pneum-operitonium(after RM), after another 30 min, at the end of the procedure, at PACU and before discharge from PACU as shown in table (4).

II – Arterial Blood Gases**PO₂/ Fi O₂****Table (5):** Showing comparison ofPO₂/ Fi O₂ values between the 4 groups in different times which presented as mean \pm SD.

PO ₂ / FiO ₂	Group A (n=25)	Group B (n=25)	Group C (n=25)	Group D (n=25)	ANOVA	
					f	P-value
Pre operative	332.45 \pm 46.85	334.37 \pm 56.12	334.09 \pm 53.3	330.12 \pm 40.08	0.039	0.990
Intra operative	314.56 \pm 51.67	317.16 \pm 45.29	312.3 \pm 47.11	313.64 \pm 36.2	0.051	0.985
Post operative	286.78 \pm 40.56	288.78 \pm 39.18	311.78 \pm 38.26	310.78 \pm 42.74	2.858	0.041*
6 hrs. post operative	281.32 \pm 36.08	283.54 \pm 32.82	305.07 \pm 41.37	307.12 \pm 39.57	3.327	0.023*

* statistically significant difference.

Regarding the value of PO₂/ Fi O₂, there is no statistically significant difference between all groups in the preoperative and intra operative values. But there is statistically significant increase in group D and group C respectively compared to group A and B in both post operative and 6 hours post operative values as shown in table (5).

The need for 100% O₂ or re-intubation in the PACU:**Table (6):** Showingthe number and percentage of patients who needed 100% O₂ or re-intubation in the PACU.

The need for 100% O ₂		Need	Didn't need	Re-intubation	Total	Chi-square	
						X ²	P-value
Group A (n=25)	N	5	19	1	25	9.295	0.026*
	%	20	76	4	100		
Group B (n=25)	N	4	21	0	25		
	%	16	84	0	100		
Group C (n=25)	N	1	24	0	25		
	%	4	96	0	100		
Group D (n=25)	N	0	25	0	25		
	%	0	100	0	100		

- Regarding the need for 100% O₂ in the PACU, there is statistically significant increase in the need for 100% O₂ in the PACU in group A and B in comparison to group C and D as shown in table (6).
- Group A showed the highest number of patients who needed 100% O₂ in the PACU, also the only patient who needed re-intubation due to significant desaturation was belonged to group A.
- Group B also showed significant number of patients who needed 100% O₂ in the PACU but less than group A.
- Group C showed only one patient who needed 100% O₂ in the PACU which statistically insignificant but group D showed the best result as no patient in this group needed 100% O₂ in the PACU.

III – CT Chest

Atelectasis Score

Table (7): Number and Percentage of Patients in the 4 Groups According to Their Atelectasis Score

CT chest	Group A (n=25)		Group B (n=25)		Group C (n=25)		Group D (n=25)		Chi-square	
	N	%	N	%	N	%	N	%	X ²	P-value
Pre operative										
Normal	25	100	25	100	25	100	25	100	0.000	1.000
Lamellar atelectasis	0	0.0	0	0.0	0	0.0	0	0.0		
Plate atelectasis	0	0.0	0	0.0	0	0.0	0	0.0		
Segmental atelectasis	0	0.0	0	0.0	0	0.0	0	0.0		
Lobar atelectasis	0	0.0	0	0.0	0	0.0	0	0.0		
Post operative										
Normal	11	44	12	48	20	80.0	22	88.0	23.47	0.024*
Lamellar atelectasis	3	12	6	24	3	12.0	2	8.0		
Plate atelectasis	6	24	5	20	2	8.0	1	4.0		
Segmental atelectasis	4	16	2	8	0	0.0	0	0.0		
Lobar atelectasis	1	4	0	0	0	0.0	0	0.0		

* Statistically significant difference.

Regarding CT chest, All pre operative images were normal in all groups. So, there is no statistically significant difference in the preoperative image between all groups. But, there is statistically significant increase in the number and percentage of atelectasis score in post operative image in both group A and B respectively in comparison to both group C and D respectively as shown in table (7).

Group A showed the highest number of both lobar and segmental atelectasis followed by group B which showed also a high number of segmental atelectasis. In despite, group C showed a higher number of plate and lamellar atelectasis followed by group D that showed a high number of lamellar atelectasis but the lowest number of other atelectasis scores.

DISCUSSION

The study was done to compare between addition of PEEP 10cmH₂O only or addition of PEEP 10cmH₂O after Recruitment Maneuver to both VCV and PCV regarding hemodynamics, Oxygenation during the intra-operative and post operative periods and their rule in prevention of

post operative atelectasis in morbid obese patients undergoing laparoscopic surgery.

The study showed that RM followed by PEEP 10cmH₂O after pneumoperitoneum is better than addition of PEEP 10cmH₂O only for oxygenation in postoperative periods. It also showed better protection against post operative pulmonary atelectasis which was evaluated by post operative chest CT scan. At the same time, it is safe regarding hemodynamics in normovolumic patients.

In the study, RM was done in the selected groups 15minutes after pneumoperitoneum as its effect may be abolished by pneumoperitoneum if RM was applied before it.

Also, RM was repeated 10 minutes later in the selected groups to ensure its effect on both oxygenation and prevention of pulmonary atelectasis postoperatively.

PEEP 10cmH₂O was added after RM till the end of the operation to keep the recruited alveoli opened.

Because the diaphragm is mechanically coupled to the abdominal wall, any increase in abdominal pressure may decrease functional residual capacity. During laparoscopy, the raised

abdominal pressure distends the abdominal wall, increases its elastance, shifts cranially the diaphragm, and moves a large part of the ventilation-related volume changes through the rib cage. The Trendelenburg facilitates the transmission of the abdominal weight to the lung parenchyma which causes worsening of respiratory mechanics⁽⁴⁾.

Reduced pulmonary compliance in obese individuals leads to decreased functional residual capacity (FRC), vital capacity and total lung capacity. Reduced FRC can result in lung volumes below closing capacity in the course of normal tidal ventilation, leading to small airway closure, ventilation-perfusion mismatch, right-to-left shunting and, ultimately, arterial hypoxemia. Anesthesia worsens this situation such that up to 50% reduction in FRC occurs in obese anesthetized patients compared with 20% in the non-obese⁽⁷⁾.

Moreover, pneumoperitoneum causes 30% lower static compliance and 68% higher inspiratory resistance in supine anesthetized obese patients compared with those of normal weight patients. During laparoscopy, diminished FRC, ventilation-perfusion mismatch and pulmonary shunting contribute to a decrease in arterial oxygenation, in addition to atelectasis formation which is further exaggerated in the obese patients⁽⁸⁾.

Ventilation-perfusion inequalities in obese patients during laparoscopy may require about 15–25% increase in minute ventilation to maintain normocarbida. But, the increase in tidal volume or respiratory rate does not improve arterial oxygenation⁽⁸⁾.

Several studies have been performed to determine the optimal ventilatory settings in these patients. The primary goal of mechanical ventilation is the maintenance of adequate gas exchange, which must be achieved with minimum lung injury and the lowest possible degree of hemodynamic impairment⁽⁹⁾.

The application of positive end-expiratory pressure (PEEP) has been shown to counterbalance the diaphragm cranial shift increasing functional residual capacity and decreasing respiratory system elastance. Recently, the application of an “open lung” strategy consisting in a recruiting maneuver (RM) followed by the subsequent application of PEEP has been suggested to effectively re-expand pneumoperitoneum-induced atelectasis and improve oxygenation during laparoscopic surgery. However, the effects of the open lung strategy on respiratory mechanics have not been thoroughly investigated⁽⁴⁾.

So, this study was performed to investigate the effect of open lung strategy on vital data, oxygenation and prevention of complications.

Regarding hemodynamics, statistics showed that they were not significantly affected after recruitment maneuver or after addition of PEEP 10 cmH₂O as the volume state of the patients was adjusted to avoid hypovolemia.

Talab et al.⁽⁶⁾ showed that application of PEEP 10cmH₂O and VCV was not accompanied by significant reduction in MAP, even after pneumoperitoneum and positioning. They explained that by sufficient preload with crystalloid solution 20ml/kg/hr for all patients.

Emmanuel et al.⁽¹⁰⁾ also confirmed the hemodynamic safety of RM and application of PEEP in intravascular volume loaded patients. Their study showed that special care had taken that the patients were normovolumic before performing RM.

Severgnini et al.⁽¹¹⁾ observed that using RM did not cause hypotension and increased requirement of vasopressors because of administration of fluid bolus before anesthesia induction and the relatively lower peak inspiratory pressure used. They also reported that the use of higher PEEP levels was not associated with major hemodynamic impairments, higher intra operative fluid requirements or blood loss, probably because they used modified RMs with a progressive increase in tidal volumes, which may have provoked less negative hemodynamic impairment than the use of sustained inflation⁽¹²⁾.

However, **Ayman et al.**⁽¹²⁾ found that a greater effect on hemodynamic parameters were observed in the patients who received protective ventilation and RMs. Indeed, hemodynamic instability requiring the administration of fluidboluses and vasopressors in 24% of the cases. This finding is consistent with that of Grasso et al who reported reduced cardiac output (CO) and MAP after the application of RMs in ARDS patients, as well as with that of Nielsen et al who reported that RMs led to a significant reduction in CO in critical care patients.

Jo et al reported decreases in MAP and HR when PEEP was added in the setting of a pneumoperitoneum⁽¹²⁾.

Regarding oxygenation, Emmanuel et al. found that PEEP10cmH₂O only partly counteracted the effect of pneumoperitoneum on respiratory system compliance without major effect on oxygenation. Other recent studies also found that PEEEP alone was insufficient to improve oxygenation during an increase in intra abdominal pressure⁽¹⁰⁾.

This can be explained as PEEP may increase the normally aerated lung fraction in parallel with a reduction in the proportion of poorly aerated lung tissue although the extent of atelectasis may remain unchanged⁽¹³⁾.

Almarkabi *et al.*⁽¹¹⁾ also found that pneumoperitoneum impaired respiratory mechanics and gas exchange, this effect led to development of atelectasis and reduced lung volumes. The decrease in respiratory system compliance and PO₂ was significantly reversed by the application of sustained inspiratory pressure combined with PEEP, but not by one intervention alone.

Also, Dyher and colleagues study showed that both lung RM and PEEP are required to maintain increased lung volume and PO₂ after cardiac surgery⁽¹⁴⁾.

In support of this, Whalen and colleagues⁽¹⁴⁾ observed sustained beneficial effects on arterial oxygenation in the majority of obese patients undergoing laparoscopic bariatric surgery after application of incremental levels of PEEP, up to 20cmH₂O, then decreased to 12cmH₂O.

In contrast, Pelosi and colleagues showed that PEEP 10cmH₂O alone increases lung compliance and PO₂ in morbidly obese patients but not in normal weight individuals. However, the disparity in the results could be explained as the patients in their study had higher BMI than those in the current study and there was no pneumoperitoneum⁽¹⁵⁾.

Emmanuel *et al.* confirmed that repeated RMs have been shown to improve both compliance and oxygenation, compared to single RM⁽¹⁰⁾.

In contrast to the current study, some studies have shown no beneficial effects of intra operative RM on PO₂ after tracheal extubation^(14,16).

The current study as well as Almarkabi *et al.* showed sustained improvement in oxygenation in the early postoperative period due to optimal alveolar recruitment and improved regional ventilation as a result of repeated RM applied intra operatively.

In support to the current study, Almarkabi *et al.* found that single RM could be attributed to partial alveolar recruitment. on the other hand, repeated RM showed sustained improvement in respiratory compliance and PO₂. This is matched with the results of Sprung and colleagues study that observed a sustained improvement in PO₂/FIO₂ and respiratory dynamic compliance in patients undergoing laparoscopic bariatric surgery when an

incremental increase in PEEP maneuver was applied hourly^(15,17).

In the current study, RM followed by PEEP 10cmH₂O was accompanied by better intraoperative and postoperative oxygenation in addition to a lower atelectasis score in chest CT scan done approximately 6 hr postoperatively in comparison to PEEP 10cmH₂O only which also improves intra operative oxygenation. But its effect is transient and could not extend to the postoperative period. This is matched also with Gilda *et al.* which concluded the same finding.

Because oxygenation alone is a poor indicator for pulmonary atelectasis, chest CT scan was done to evaluate postoperative atelectasis and its score.

In this study, no pneumothorax, air in the mediastinum or subcutaneous emphysema was detected in chest CT scan done postoperatively in any patient in the 4 study groups. in the RMs groups, less than 20% developed postoperative atelectasis (lamellar more than platel atelectasis) while about 50% of patients from the PEEP only group developed postoperative atelectasis (between lamellar and palatal type, but few patients also developed segmental atelectasis).

In support to our study, Ayman *et al.*⁽¹²⁾ found that protective ventilation was superior to conventional ventilation in the prevention of atelectasis, as reflected by a higher atelectasis score in the standard ventilation group, in which 52% of the patients developed atelectasis (40% showed lamellar atelectasis and 12% showed plate atelectasis), compared to 36% of the patients in the protective ventilation group (all these cases revealed lamellar atelectasis). This finding is consistent with that of **Coussa *et al.***⁽¹⁸⁾ study who reported similar results and concluded that the application of PEEP (10 cm H₂O) in morbidly obese patients was very effective in preventing atelectasis during the induction of general anesthesia.

Also, Barbosa *et al.* performed a meta-analysis and suggested that an open lung approach with PEEP in surgical patients improves postoperative oxygenation and decreases postoperative atelectasis without any adverse events⁽¹⁹⁾.

In contrast, another study⁽⁶⁾ who found that VCV alone could completely abolish atelectasis that develop after induction of general anesthesia. This can be the difference in patient selection because they applied the VCV to non obese patients undergoing non laparoscopic surgery compared to obese patients undergoing laparoscopic surgery in our study.

Postoperative pulmonary complications that occurred can be explained by the increased frequency of atelectasis in the affected groups. The adverse effects of atelectasis persist into the postoperative period and can affect patient recovery. The absence of pulmonary complications in groups with RM can be attributed to less atelectasis in those patients.

The same findings was reached by Michelle et al. (20) study who reported that development of atelectasis is associated with decreased lung compliance, impairment of oxygenation, increased pulmonary vascular resistance and development of lung injury.

Many previous studies have investigated postoperative hypoxemia in the PACU. Mathes et al. found that, on arrival to the PACU, 20% of patients may have an oxygen saturation <92% and in 10% the saturation may be <90%. Xue et al. reported that, in the PACU within 3 hours of surgery, 7% of patients will have at least 1 episode of desaturation <90% and 3% will desaturate to <85%. Russel and Graybeal reported that, despite the use of 40% oxygen given by facemask, 15% of patients in the PACU will have oxygen saturation <92% lasting > 30 s. This event lead leads to prolonged PACU stay and causes more ICU admissions. In all previous studies, all patients were anesthetized with VCV without any recruitment maneuver (6).

Therefore, repeated RMs in conjunction with PEEP may represent an "optimal" open lung approach.

The current study has may limitations. Firstly, patients with BMI >50kg / m² were excluded although the severity and effect of atelectasis are expected to be increased in those patients. But, the standard CT scan table cannot support patients weighing >170 kg and we needed to evaluate postoperative atelectasis by CT scan.

Secondly, the study time was limited to the early post operative period only. so, we cannot exclude later variation in the measured parameters or later complications. But, many other factors may be involved in late pulmonary complications.

In the current study, with respect to the indices of carbon dioxide elimination, PaCO₂ was adjusted by the ventilator settings throughout the procedure to maintain EtCO₂ between 32-35 mmHg.

CONCLUSION

In conclusion, repeated Recruitment Maneuvers combined with 10 cmH₂O of PEEP have beneficial effects on oxygenation continued into the early recovery period and decrease pulmonary complications in the early post

operative period in morbid obese patients undergoing laparoscopic surgery.

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