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ORIGINAL RESEARCH **ANESTHESIA FOR BARIATRIC SURGERY**

Effect of pressure support ventilation vs. spontaneous ventilation on lung atelectasis during recovery from anesthesia for laparoscopic gastric sleeve surgery

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ABSTRACT

Background & Objective: Pressure support ventilation (PSV) is a target pressure mode that offers breath by breath mode of ventilation support, started by patients, and timed to respiratory effort. The fundamental idea behind PSV is to assist spontaneous breathing in response to the patient-initiated breaths. We evaluated the effects of PSV and spontaneous ventilation during awakening from anesthesia on lung atelectasis in the patients following laparoscopic gastric sleeve surgery.

Methodology: Following clearance from the institutional ethical council, we enrolled 64 patients and divided them into two groups at random; pressure support group (Group PS) to receive PSV, and control group or spontaneous group (Group S) to continue with spontaneous ventilation mode during awakening from anesthesia in the patients following laparoscopic gastric sleeve surgery.

Results: In the pressure support group, atelectasis was less common than in the control group at PACU (P = 0.042). Over the first 48 h following surgery, there were substantial differences between the groups in the level of oxygen saturation as determined by pulse oximetry ≤ 92%. The incidence of SpO_2 ≤ 92% during 48 h postoperatively in the Group S and Group PS was 34% vs 12% respectively. No patient needed mechanical ventilatory support during the 48 h postoperatively.

Conclusions: Pressure support ventilation during the recovery from general anesthesia to patients after laparoscopic gastric sleeve surgery resulted in reduced incidence of postoperative atelectasis than those who were allowed spontaneous ventilation with occasional manual support.

Abbreviations: PACU: Post-Anesthesia Care Unit; PEEP: Positive End Expiratory Pressure; PSV: Pressure support ventilation; V_T: Tidal Volume.

Key words: Gastric sleeve surgery; Laparoscopy; Lung atelectasis; Pressure support ventilation; Spontaneous ventilation.

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1. INTRODUCTION

The majority of anesthetized patients experience atelectasis in the dependent areas of their lungs as a result of several circumstances, including decreased compliance of the lung, impaired oxygenation, raised pulmonary vascular resistance and the pulmonary barotrauma. The negative effects of collapse can affect a patient's recovery even after surgery.[1]

Clinical risk factors for perioperative atelectasis include obesity, acute lung inflammation, respiratory and diaphragmatic muscle dysfunction; increased intra-abdominal pressure, and chronic pulmonary congestion, as examples of risk factors specific to the patient. High fraction of inspired oxygen, low tidal volume (V_T) without positive end expiratory pressure (PEEP), inadequate neuromuscular blockade reversal, hypervolemia and transfusion related acute lung damage are some problems associated with anesthesia. One-lung breathing, pneumoperitoneum, Trendelenburg, supine, and lateral body postures are all factors associated to surgery.[2]

Fewer studies have focused on the time following recovery from anesthesia, despite the fact that many studies have been conducted on ventilation strategies to lower pulmonary problems postoperatively.[3,4] The recruitment procedure and the use of PEEP increased intraoperative oxygenation, but the benefit quickly vanished following extubation. In numerous investigations, the emerging phase has been shown to be the one during which atelectasis will develop. The percentage of postoperative atelectasis during the emerging period has been predicted to be 39% of the total.[5, 6.]

A safe, precise imaging method at the bedside is lung ultrasonography, which also makes it easier to diagnose respiratory issues by tracking perioperative atelectasis.[7]

Pressure support ventilation (PSV) is a pressure mode that offers breath to breath ventilation support that is always initiated by the patient and timed to the respiratory effort. The fundamental idea behind PSV is to assist spontaneous breathing in response to patient-initiated breaths. Patient-triggered PSV might be flow- or time-cycled. The patients must be breathing on their own for PSV to be useful when under clinical anesthetic.[8]

We evaluated the effects of the PSV and the spontaneous breathing during awakening from general anesthesia on postoperative lung collapse (atelectasis), in patients following laparoscopic gastric sleeve surgery.

The primary outcome was the lung ultrasound findings of atelectasis in the post anesthesia care unit (PACU). And the secondary outcomes were SpO_2 in recovery determined by pulse oximetry within the first 48 h after surgery higher than 92%.

2. METHODOLOGY

The Research Ethics Committee approved this prospective, double-blind, randomized controlled study (Letter No.: 001756). Written informed consent was obtained from each patient before surgery.

Eighty-six patients were assessed for eligibility during a period between March 2022 to February 2023; and 64 patients out of them were selected and randomly divided into two groups using a computer-generated table and sealed, opaque envelopes as shown in the CONSORT flow diagram (Figure 1).

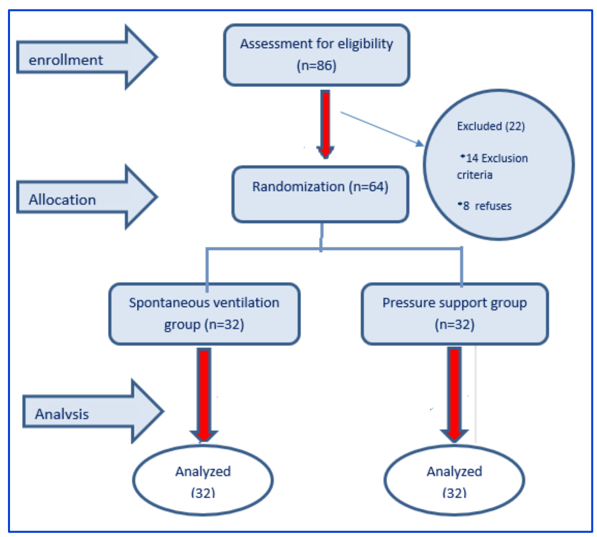

Figure 1: CONSORT flow diagram.

Patients in Group PS (n = 32) obtained PSV during recovery period, and Group S (Control group) patients (n = 32) were kept on spontaneous ventilation with 3−4 L oxygen delivered through nasal cannula.

The inclusion criteria included patients from both sexes, ages 25−50 y, ASA physical status II or III, planned for an elective laparoscopic gastric sleeve procedure lasting more than 60 min in the anti-Trendelenburg position.

Heavy smokers, pregnant females, patients with history of obstructive lung disease, pulmonary tuberculosis, pneumothorax, previous lung surgery and pleural effusion or abnormal oxygen saturation were excluded.

Patients in which difficult intubation was expected, and those with any history of previous anesthetic respiratory complications were also excluded. Patients, who refused to participate in the study were excluded.

2.1. Anesthetic technique

Every patient underwent a pre-anesthesia evaluation that included a review of their history, a physical exam, and a review of laboratory studies.

The day before surgery, a chest x-ray was taken to rule out any existing lung disease. An initial lung ultrasound was performed in the waiting area.

After routine monitoring, propofol 2.0 mg/kg and fentanyl 2 mg/kg were used to induce anesthesia. Atracurium 0.5 mg/kg was added after that, and an appropriate-sized cuffed endotracheal tube passed. Isoflurane (MAC = 1.2) was used to maintain anesthesia, and mechanical ventilation adjusted to maintain end-tidal carbon dioxide at 35–40 mmHg. In both groups ventilator settings were set to deliver a tidal volume of 8 ml/kg of estimated body weight, inspiratory to expiratory ratio 1: 2, PEEP 5 cmH_2O and a respiratory rate of 12 breaths per min.

A bolus of fentanyl 0.5 µg/kg was administered if hypertension (MBP > 20% above the baseline) or tachycardia were developed. Atracurium 0.1 mg/kg was given as needed and discontinued 30 min before the end of surgery. When the train of four (TOF) counts reached 3 or 4, the recovery protocol was started, and isoflurane was switched off.

Group PS patients received PSV to achieve the target V_T in the range of 7−8 ml/kg and respiratory rate 12−16 breaths/min. The following settings were used: driving pressure of 10 cmH_2O, PEEP of 5 cmH_2O, and safety backup ventilation of 12 breaths/min. These settings were gradually reduced as the patient's own V_T and RR were regained. In the Group S, the fundamental approach was to let the patient breathe on their own and only provide intermittent physical support with respiration if it becomes essential.

Throughout recovery TOF was monitored in both groups. Neostigmine (0.04 mg/kg) and atropine (0.01 mg/kg) were used to reverse residual neuromuscular blockade if the TOF count was three or higher.

Extubation criteria included $V_T \geq 350$ ml, $EtCO_2 \leq 45$ mmHg, RR 12−18 breaths/min, and TOF ratio greater than 0.9. All patients were sent to the PACU with 2 L/min of oxygen support after being extubated. The time from the end of anesthesia until tracheal extubation (emergence time) was noted in every patient.

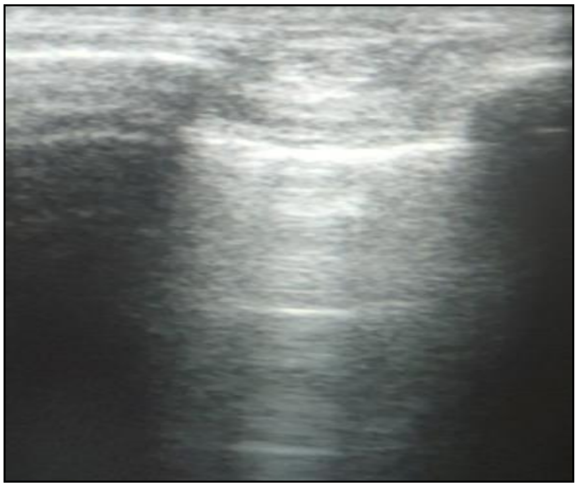

Figure 2: Normal Lung. Pleura as a thin white line, horizontal A-line and ribs on both sides (score 0).

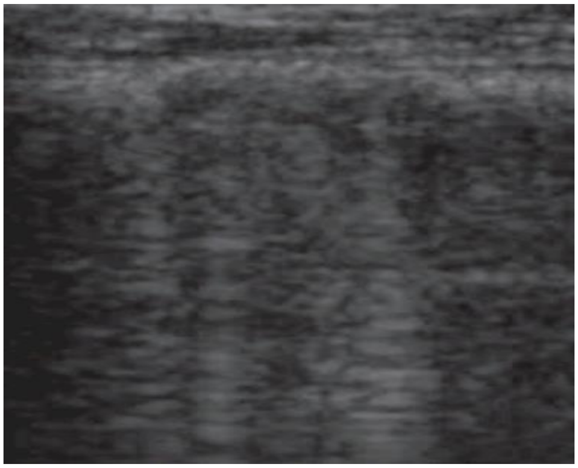

Figure 3: More than three well-spaced vertical lines per intercostal space (B-lines) (Score 1).

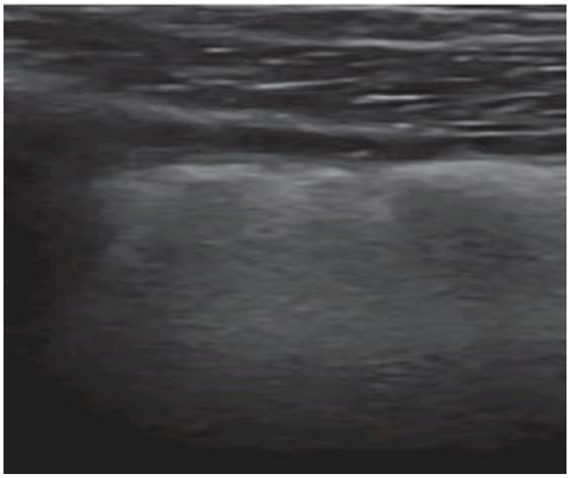

Figure 4: Loss of A-line with multiple juxtapleural consolidations and irregular pleural lines are seen (Score 2).

Every 15 min, hemodynamics, RR, $EtCO_2$, and SpO_2 were monitored in the PACU. Any oxygen saturation fall ≤ 92%, or occurrence of agitation were noted.

Every 8 h for the first 48 h following surgery, any respiratory symptoms, e.g., cough, secretions, and sore throat, were assessed.

Lung ultrasonography was used to assess all patients at 30 min after their arrival in the PACU, performed by the pulmonologist author (Fareed S B H) with 3 y of experience and blinded to the studied groups

Table 1: Basic data of study population.

Parameters	Group S N = 32	Group PS N = 32	Test value	p-value
Age (y) (mean ± SD)	38.55 ± 5.92	36.6 ± 6.15	-1.272	0.208
Sex (n) (%)				
○ Male	14 (43.8)	13 (40.6)	0.064	0.800
○ Female	18 (56.3)	19 (59.4)		
ASA (n) (%)				
○ II	29 (90.6)	30 (93.8)	0.217	0.641
○ III	3 (9.4)	2 (6.3)		
BMI (kg/m_2) (mean ± SD)	38.27 ± 1.31	38.8 ± 1.57	1.447	0.153
Co-morbid conditions (n) (%)				
○ Hypertension	10 (31.3)	12 (37.5)	0.277	0.599
○ Diabetes	6 (18.8)	5 (15.6)	0.110	0.740
○ Cardiovascular disease	1 (3.1)	1 (3.1)	0.000	1.000
Surgery time (min)	93.7 ± 13.58	90.3 ± 11.74	-1.051	0.297
Emergence time (min)	10.5 ± 2.7	11.9 ± 3.2	1.8915	0.0632
Difficult intubation	2 (6.3)	1 (3.1)	0.350	0.554
SpO_2 ≤ 92% during Surgery	3 (9.4)	2 (6.3)	0.217	0.641

Data presented as n (%) or Mean ± SD

2.2. Lung ultrasound and scoring of atelectasis

There are 5 scores of lung atelectasis:

0: Normal lung; A-lines are apparent and pleura is thin. One or two well-spaced lines per intercostal space are allowed, as in Figure 2.

1**:** More than three well-spaced vertical lines per intercostal space (B-lines), as in Figure 3.

2*:* Loss of A-line with multiple juxtapleural consolidations and irregular pleural lines are seen, as Figure 4.

3**:** Loss of lung sliding and appearance of lung pulse.

4: Large consolidation.

2.3. Sample size calculation

Using the Epi Info™ mobile application version 7.2.4.0 (2020) (Stat-Calc), the sample size was calculated. The power of the research was set at 85%, the confidence level was set at 95% and an error of 5%. According to the study by Jeong et al.[9] which included 97 patients, it was determined that the pressure support group had a lower incidence of collapse at (PACU) than the control group.

2.4. Statistical analysis

Continuous variables are defined using a measure of dispersion called standard deviation and a measure of central tendency called mean. To indicate qualitative traits, both percentages and absolute numbers have been employed. Bivariate analysis is used to compare the study groups (Groups S and PS). Shapiro-Wilk test was used to check the normality of the continuous dependent variables. Non-paired samples were subjected to the Student's t-test in order to assess the normal variables. The two groups were compared by an impartial t-test. Non-parametric data was evaluated by Mann-Whitney test and the categorical difference using chi-square test.

3. RESULTS

Regarding the basic data, no significant difference was found between both groups regarding age, ASA physical status, BMI, gender, operative time and emergency time. Also, there was no significant difference in co-morbid conditions (P > 0.05) between the groups (Table 1).

The hemodynamic and respiratory data including HR, MAP, $EtCO_2$ level and RR (P > 0.05) as shown in Table 2, were comparable in both groups and there was no significant difference between the two.

Table 3 shows a reduced incidence of atelectasis postoperatively (28% vs. 53%) in Group PS as compared to Group S. The most findings of atelectasis were scoring 2 = loss of-A-lines with multiple juxta consolidations of the pleura, and uneven and pleural lines, followed by 1 = multiple-B-lines.

Table 2: Hemodynamic Parameters

Parameters	Group S N = 32	Group PS N = 32	Test value	p-value
MAP (mmHg)	83 ± 7	81 ± 6	-1.204	0.233
HR (beats/min)	76.12 ± 3	74.56 ± 4	-1.744	0.086
RR (breaths/min)	13.55 ± 0.68	13.38 ± 0.43	-1.168	0.248
End-tidal CO2 (mmHg)	36.3 ± 1.50	37 ± 1.76	1.689	0.096

Data presented as mean ± SD; P ≤ 0.05 is considered significant.

Table 3: Postoperative atelectasis at post anesthesia care unit.

Parameter	Group S n = (32)	Group PS n = (32)	Test value	P-value
Atelectasis detected with lung ultrasonography	17 (53.1)	9 (28.1)	4.146	0.042*
Atelectasis score	2 (1–2)	1 (1–2)	0.994	0.320

*Data presented as mean ± SD; P ≤ 0.05 is considered significant; * Significant*

As regarded to postoperative complication in between groups, no statistical variation between both groups in relation to fever, agitation, disorientation and respiratory problem see in Figure 3.

Table 4 show that % of patients with $Spo_2 \leq 92\%$ during the stay in PACU was 37% vs 15 % in spontaneous and pressure support ventilation groups, respectively. Higher Pao_2 at PACU with pressure support ventilation group (94 ± 19 mmHg vs 85 ± 15 mmHg) in spontaneous \

ventilation group. At the ward, the incidence of Spo_2 ≤92% during 48h postoperatively was 34% vs 12 % in the spontaneous and pressure support ventilation groups, respectively.% of patients needed oxygen therapy to maintain $Spo_2 > 92\%$ were (28% vs 9%) in spontaneous group and pressure support group. No patient needed ventilatory support during the 48h postoperatively.

Postoperative complications in were comparable in the groups, with no statistical differences in the frequency of fever, agitation, disorientation and respiratory problems.

4. DISCUSSION

In the current study, there were no significant differences in the demographic data, or co-morbid conditions (P > 0.05) between the groups (Table1). No significant differences were found between groups regarding the effects on the heart rate, MAP, $EtCO_2$ and

Table 4: Secondary Outcomes of the study.

Parameter	Group S n = (32)	Group PS n = (32)	Test value	P-value
PaO_2 (mmHg) measured at PACU	85 ± 15	94 ± 19	2.103	0.040*
$SpO_2 \leq 92\%$ at PACU	12 (37.5%)	5 (15.6%)	3.925	0.048*
At the ward				
$SpO_2 \leq 92\%$ during postoperative 48 h	11 (34.4%)	4 (12.5%)	4.267	0.039*
Number of patients needing oxygen supplementation 48 h postoperatively.	9 (28.1%)	3 (9.4%)	3.692	0.055
Number of patients needing mechanical ventilation support	0 (0.0%)	0 (0.0%)	-	-
Hospital stay postoperatively (days)	5.59 ± 0.78	6.02 ± 1.21	1.690	0.096

*Data presented as mean ± SD; P ≤ 0.05 is considered significant. * Significant* respiratory rate. Soaida et al. studied PSV in the infants with long duration surgery without muscle relaxants, and found it was efficient in preserving normal V_T while avoiding fatigue to keep $EtCO_2$ levels and hemodynamics within normal ranges.[8]

Lourenco et al. found that the patients who underwent cardiac operations with cardiopulmonary bypass were not affected by the two experimental techniques assessed for interruption of ventilation.[10]

Modern anesthesia machines come equipped with PSV techniques, which are also frequently employed while patients are waking up from anesthesia.[9] PSV is also frequently used to wean patients off ventilators in intensive care units.[11] It has been advised by the American Thoracic Society guidelines for effective weaning.[12]

The present study demonstrated that, Group PS was associated with a reduced frequency of postoperative atelectasis and higher oxygenation in contrast to the Group S in laparoscopic gastric sleeve surgery. No significant differences were detected between the two groups as regards to the patient's hemodynamic parameters. In consistent with our results, Jeong and his colleagues, studied 97 patients, aged ≥ 20 y scheduled for elective laparoscopic colon resection or robot assisted laparoscopic prostatic resection to compare PSV and spontaneous ventilation effect on postoperative collapse during anesthetic emergence. They found that the incidence of collapse at PACU was lower and PaO_2 was greater in the PS group than in the control group with no significant differences between the two groups as regards to patient's hemodynamics.

Ventilation with pressure support PEEP raises end-expiratory lung volume and neutralizes airway closure with a dominant implication in the dependent lung region, which is enough to avoid or reverse atelectasis in healthy lungs of the patients undergoing surgery. Postoperative atelectasis is diagnosed by ultrasonography and may have contributed to the reduced risk of this condition.[13] Also, in inspiratory pressure support, driving pressure improves lung expansion during inspiration and decrease the work of breathing.[14] A meta-analysis was done by Sklar et al. [14] to assess the effort to breathe with various spontaneous breathing trial techniques. They concluded that PSV reduces respiratory effort compared to T-piece.

On the other hand, Pellegrini et al.[15] reported that in patients in the ICU, elevated continuous positive airway pressure decreased respiratory drive and the diaphragm's contractile activity.

The incidence of fall of $SpO_2 \leq 92\%$ at PACU was significantly higher (37% vs. 15%) in Group S than PS group in our study. In the ward, this incidence within the first 48 h postoperatively was 34% vs. 12% respectively in the groups.

In disagreement with our results, Jeong et al.[9] found no significant differences between the studied groups regarding the frequency of oxygen saturation fall below 92% as assessed by pulse oximetry in the 48 hours following surgery.

In a study carried out by Tokioka et al.[16] on six children aged 3–5 y in the postoperative period after cardiac surgery, different levels of pressure support were used, and the V_T, minute volume, airway pressure, and RR were measured. They reported that the mechanical work of breathing decreased with higher levels of pressure support (10 cmH_2O) and concluded that PSV can effectively augment spontaneous breathing and reduce the work of breathing in children.

Regarding postoperative complications, no patient in both groups, and needed ventilatory support during the 48 h postoperatively. No patient developed acute renal injury or respiratory problems. Only one patient in each group developed agitation and one patient in spontaneous group developed disorientation.

This trial adds to the current evidence regarding use of PSV during recovery of laparoscopic gastric sleeve surgery to reduce the frequency of postoperative atelectasis in high-risk patients.

5. CONCLUSIONS

Pressure support ventilation of the patients after laparoscopic gastric sleeve surgery during recovery from general anesthesia reduces frequency of postoperative atelectasis as compared to oxygen supplementation on spontaneous breathing with occasional manual support.

6. Limitations to our study

The period of follow up was short. The studied patients and the staff needed much counselling to make them co-operative.

7. Data availability

The numerical data generated during this study is available from the corresponding author.

8. Conflict of interests

No conflict of interests declared by the authors.

9. Funding

No external or industry funding was involved in this study.

10. Authors' contribution

MAAA: Conduction of the study.

AEAF: Literature search and editing.

FSBH: Statistical analysis and design.

AMA: Manuscript editing and final review.

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