Equal ratio ventilation (1:1) improves arterial oxygenation during laparoscopic bariatric surgery: A crossover study

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A B S T R A C T

Background: Hypoxaemia and high peak airway pressure (Ppeak) are common anesthetic problems during laparoscopic bariatric surgery. Several publications have reported the successful improvement in arterial oxygenation using positive end expiratory pressure and alveolar recruitment maneuver, however, high peak airway pressure during laparoscopic bariatric surgery may limit the use of both techniques. This study was designed to determine whether equal I:E (inspiratory-to-expiratory) ratio ventilation (1:1) improves arterial oxygenation with parallel decrease in the Ppeak values. **Methods:** Thirty patients with a body mass index ≥ 40 kg/m^2 scheduled for laparoscopic bariatric surgery were randomized, after creation of pneumoperitoneum, to receive I:E ratio either 1:1 (group 1, 15 patients) or 1:2 (group 2, 15 patients). After a stabilization period of 30 min, patients were crossed over to the other studied I:E ratio. Ppeak, mean airway pressure (Pmean), dynamic compliance (Cdyn), arterial blood gases and hemodynamic data were collected at the end of each stabilization period. **Results:** Ventilation with I: E ratio of 1:1 significantly increased partial pressure of O_2 in the arterial blood (PaO$_2$), Pmean and Cdyn with concomitant significant decrease in Ppeak compared to ventilation with I: E ratio of 1:2. There were no statistical differences between the two groups regarding the mean arterial pressure, heart rate, respiratory rate, end tidal CO$_2$ or partial pressure of CO$_2$ in the arterial blood. **Conclusion:** Equal ratio ventilation (1:1) is an effective technique in increase PaO$_2$ during laparoscopic bariatric surgery. It increases Pmean and Cdyn while decreasing Ppeak without adverse respiratory or hemodynamic effects.

Key words: *Ventilation, laparoscopic, bariatric surgery, I:E ratio, oxygenation, crossover study*

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INTRODUCTION

Arterial oxygenation is impaired during general anesthesia to a greater extent in obese compared with normal-weight patients.[1] Increased intrathoracic pressure during abdominal laparoscopy aggravate this impairment by reducing respiratory system compliance and lung volumes.[2-5] Different ventilatory strategies have been proposed to improve pulmonary gas exchange during laparoscopic bariatric surgery. Applying positive end expiratory pressure (PEEP) and/or alveolar recruitment maneuver (ARM)were found to induce significant improvement in gas exchange status but, however, their use is sometimes limited by the significantly concomitant increase in Ppeak with increased risk of barotrauma.[6-9]

Inverse ratio ventilation (IRV) has been proposed for patients with adult respiratory distress syndrome to achieve adequate oxygenation.[10,11] Prolonging I:E ratio increases Pmean and Cdyn while decreases Ppeak. This would recruit atelectatic alveoli and hence improves arterial oxygenation.[7,12] Owing to these theoretical advantages, and our clinical experience, we suggested that, ERV will improve arterial oxygenation in patients undergoing laparoscopic bariatric surgery compared to conventional 1:2 ratio ventilation.

METHODS

After approval from the ethics committee of the University of Dammam, Dammam, Saudi Arabia, a written consent was taken from 30 patients scheduled for laparoscopic gastric band ligation were prospectively enrolled to this crossover study. All patients were ASA physical status I and II between 25 and 45 years old with a body mass index (BMI) above 40 kg/m², without significant obstructive or restrictive pulmonary disease (defined as <70% of predicted values for pulmonary function test variables of volume and flow or $PaCO_2 > 45$ mmHg), no active asthma (requiring chronic bronchodilator therapy) and no significant cardiac dysfunction (left ventricular ejection fraction ≤40%). All patients received 250 ml of colloids before induction of anesthesia; crystalloids were then infused during operation at a basal rate of 6 ml kg/h. A standardized anesthetic regimen was used and all drug dosages were calculated per kg linear body weight. General anesthesia was induced with propofol (2 mg/kg) and fentanyl (2 μg/kg). Orotracheal intubation was facilitated with rocuronium 0.6 mg/kg. Anesthesia was maintained with sevoflurane to maintain a BIS value of 45-60. Fentanyl was continuously infused during surgery at rate of 1 μg/kg/h. Muscle relaxation was monitored by the train-of-four stimulation on the ulnar nerve (GE Healthcare Finland Oy, Type E-NMT-00, Helsinki, Finland). If a visible T1 response appeared, a bolus of rocuronium 10 mg was administered.

Electrocardiogram, pulse oximetry and invasive arterial blood pressure measurement in a radial artery were continuously monitored during the surgery. Mechanical ventilation was conducted with Datex-Ohmeda, Bromma-Sweden. Pressure controlled ventilation (PCV) with a decelerating flow was started with the fraction of inspired oxygen (FiO_2) set at 50% in air and a PEEP was set to five. Absence of auto-PEEP was assured by observing the expiratory flow on the flow-time curve. Set pressure was manipulated to deliver a tidal volume (VT) of 8 ml/kg throughout surgery (a variation of <5% was accepted). Respiratory rate (RR) was manipulated to maintain an end tidal carbon dioxide tension ($EtCO_2$) of 35-40 mmHg. Carbon dioxide pneumoperitoneum was induced with 14 mm Hg intra-abdominal pressure in the supine position after which a 20° reverse Trendelenburg's position (RTP) was maintained throughout the surgical procedure. Ten minutes after pneumoperitoneum and before the start of surgery, I:E ratio was set to either 1:1 (group 1, 15 patients) or 1:2 (group 2, 15 patients) according to a computer-generated randomization schedule and sealed opaque envelopes. After a stabilization period of 30 min following patient positioning and abdominal insufflations, the first set of data were collected that included Ppeak,

Pmean, dynamic compliance (Cdyn), $EtCO_2$, mean arterial pressure (MAP), and heart rate (HR). Arterial sample was taken for PaO_2, $PaCO_2$. After 30 min, I:E ratio was changed in both group. In Group 1, I:E ratio was changed to 1:2 and in Group 2, to 1:1. After stabilization period of 30 min. data were taken again in this setting. All statistical data with I:E ratio 1:1 were collected in a new Group: A. Similarly all statistical data with I:E ratio 1:2 were collected in group B.

Data are expressed as mean ± SD. Statistical analysis was performed between group 1 and 2 (n=15) using the independent t test for the demographic data, duration of surgery and to exclude the possibility of the carryover effect in the above-mentioned respiratory and hemodynamic variables. Given that there was no such effect, Data of all patients in Group A (n=30) and Group B (n=30) regardless of the sequence of the I:E ratio applied first or second in each group were analyzed using paired t test. Data analysis was performed using SPSS, version 16 (IBM, Somers, NY, USA). A probability level of 0.05% was considered significant.

We chose to test the null hypothesis that equal ratio ventilation (ERV) (1:1) has no effect on PaO_2; this was chosen as the primary outcome measure. Secondary outcomes were Ppeak, Pmean and dynamic chest compliance. To estimate the sample size, a pilot study was conducted on 10 patients (who were not included later in our study). A total of 30 patients were needed to enter this two-treatment crossover study. The probability is 90% that the study will detect a treatment difference at a two-sided 0.05 significance level. This is based on the assumption that the within-patient standard deviation of the response variable is 28.5.

RESULTS

Thirty patients were recruited into the study. No patient was excluded for any reason. No significant differences were detected between group 1 and 2 (n=15) regarding patient characteristics and duration of surgery [Table 1]. Comparison of the respiratory and hemodynamic variables between group 1 and group 2 [Table 2] showed that the effect of the first condition did not "carryover" to the second.

As shown in [Table 3], [Figures 1 and 2], Pmean, PaO_2, Cdyn were significantly increased during ERV 1:1 (group. A) compared to the conventional 1:2 ratio (group. B) (P=0.009, 0.00, 0.00 respectively) Peak was significantly decreased in group A compared to group B (P=0.00). There were no statistical differences between the two groups regarding the MAP, HR, RR, $EtCO_2$ or $PaCO_2$. No auto-peep was detected in any patient.

DISCUSSION

This study demonstrated significant increase in PaO_2, Pmean and Cdyn during PC ERV compared to conventional PC 1:2 whereas significantly less Ppeak was required to maintain similar TV in the 1:1 ratio.

During pneumoperitonium, the intrathoracic pressure increases with consequential decrease in lung compliance, diminution of lung volumes and increase of Ppeak. This results in early airway closure and atelectasis in the dependent parts of the lungs.[5] Obese patients are more predisposed to atelectasis due to reduction of functional residual capacity and decreased compliance of both chest wall and lungs.[2-4] Increasing either the tidal volume or respiratory rate failed to improve PaO_2 during laparoscopy in morbidly obese patients,[13] while applying PEEP[7] or ARM during either laparoscopic bariatric surgery[6,8,14] or laparoscopic surgery in obese patients[15] could improve PaO_2 but was associated with significantly higher Ppeak.

IRV is a well known technique for improving arterial oxygenation in ARDS. It increases the Pmean, recruits atelectatic alveoli, reduces arteriovenous shunting, improves ventilation-perfusion matching and decreases dead space ventilation.[10,12] Prolongation of the inspiratory time allows resetting of the targeted pressure to a lower value that keep similar TV with consequent decrease in Ppeak.
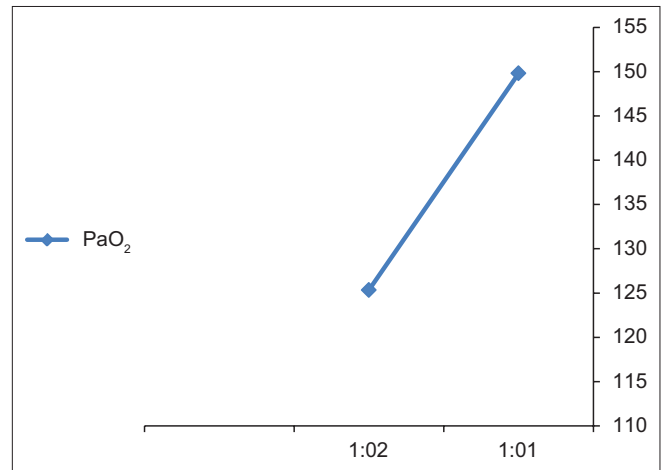
Table 1: Demographic data and duration of surgery

	Group (1) (n=15)	Group (2) (n=15)	P level
Male/Female	5/10	4/11	
Age	35.40±5.72	34.73±5.27	0.750
Weight	129.40±11.27	128.87±9.69	0.384
BMI	48.93±2.43	49.27±1.91	0.475
Height	162.53±6.01	161.27±5.46	0.942
Duration of surgery (min)	109±7.27	107.60±7.61	0.917

BMI - Body mass index; (n=15)

Table 2: Respiratory and hemodynamic data

	Group (1) Ratio 1:1 first (n=15)	Group (2) Ratio 1:2 first (n=15)	P level
PaO_2 (1:2)	128.40±27.84	122.67±24.32	0.579
Po_2 (1:1)	150.93±27. 02	148.67±23.15	0.405
$PaCO_2$ (1:2)	41.80±1.52	42.20±1.70	0.681
$PaCO_2$ (1:1)	41.87±1. 81	41.27±1.44	0.771
$ETco_2$ (1:2)	37.07±1.03	37.67±0.98	0.666
$ETco_2$ (1:1)	37.13±0.92	37.53±1.19	0.591
Ppeak (1:2)	32.27±1.75	31.33±2.35	0.336
Ppeak (1:1)	28.67±1.80	27.60±2.29	0.564
Pmean (1:2)	10.67±0.98	10.87±1.19	0. 523
Pmean (1:1)	11.33±1.29	11.47±1.25	0.883
Cdyn (1:2)	27.20±5.03	25±4.51	0.868
Cdyn (1:1)	29.67±5.53	27.27±4.56	0.605
RR (1:2)	15.73±0.80	16.00±0.85	0.668
RR (1:1)	15.47±1.19	15.67±0.98	0.278
MAP (1:2)	83.67±3.92	80.87±4.52	0.794
MAP (1:1)	83.67±3.46	81.67±3.89	0.735
HR (1:2)	63.80±6.58	65.73±6.68	0.765
HR (1:1)	65.87±6.62	65.20±7.16	0.564

RR - Respiratory rate; MAP - Mean arterial pressure; HR - Heart rate; (n=15)

Table 3: Respiratory and hemodynamic data

	Group A (1:1) (n=30)	Group B (1:2 ratio) (n=30)	P level
PaO_2	149.80±24.75	125. 53±25.85	0.000*
$PaCO_2$	42.00±1.60	41.57±1.63	0.114
$ETco_2$	37.33±1.06	37.37±1.03	0.813
RR	15.57±1.07	15.87±0.82	0.107
Ppeak	28.11±0.38	31.8±0.38	0.000*
Pmean	11.40±1.25	10.77±1.07	0.009*
Cdyn	28.47±5.13	26.23±4.80	0.000*
MAP	82.67±3.75	82.27±4.39	0.668
HR	65.53±6.78	64.77±6.59	0.254

*(P<0.05) MAP - Mean arterial pressure; HR - Heart rate; (n=15)

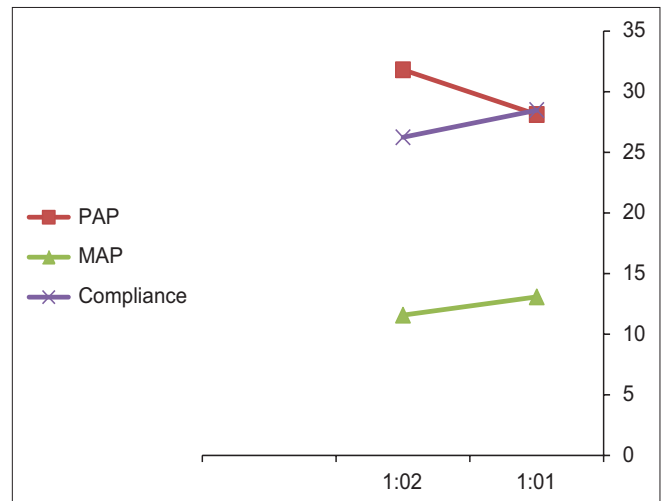**Figure 1:** Pao_2 during 1:1 and 1:2 ratio ventilation

Figure 2: Ppeak, Pmean, Cdyn during 1:1 and 1:2 ratio ventilation

Extending the inspiratory time enhances the clearance of carbon dioxide. PC-IRV has been found to improve $PaCO_2$ more than PCV 1:2[16,17] or volume-cycled ventilation with PEEP do.[16,17] A crossover study[10] evaluated eight patients with ARDS in whom six hours of volume-controlled IRV was compared with six hours of conventional ventilation showed modest improvement in CO_2 while on IRV. In our study, the $PaCO_2$ was comparable between groups and no significant adjustment in respiratory rate was needed to keep comparable $ETCO_2$ and $PaCO_2$. This may be attributed to the different type of patients in our study who might not were in need for this improvement in CO_2 elimination conditions. Also, this study was not powered to detect the effects of 1:1 ratio ventilation on $PaCO_2$.

Positioning of the obese patients during surgery has major effects on diaphragm layout, lung volumes and pulmonary function.[18,19] The 20° RTP position, as in our study, has been shown[20] to improve the Pmean and hence arterial oxygenation during bariatric surgery. On the other hand, overweight patients with BMI (25-29.9 kg/m²), subjected to endoscopic robot-assisted radical prostatectomy in Trendelenburg position, showed significantly lower PaO_2 and higher alveolar–arterial PaO_2 gradient compared with normal weight patients.[21] To unify the possible effects of positioning on our results, we started to count up for the 1st 30 min stabilization period only after patients were put in RTP that was maintained throughout surgery.

Decreasing the expiratory time when crossing over from 1:2 to 1:1 ratio might lead to air trapping in the lungs with generation of auto PEEP that could impede venous return with possible consequent hemodynamic derangement. Our results showed no formation of the aforementioned PEEP. This is in agreement with other studies that showed stable hemodynamics during PC IRV of 2:1 in trauma[22] and adult respiratory distress syndrome patients[16] and in laparoscopy for gynecological procedures.[23] Also, hemodynamic stability was also maintained during crossing over from 1:1 to 1:2 ratio albeit the significant increase observed in Ppeak. Sprung et al.[13] suggested that lowering of lung compliance prevents transmission of high inspiratory pressure to intrapleural space. They demonstrated in their study that cardiac output and other hemodynamic parameters were not influenced in morbidly obese patients by high inspiratory pressures during pneumoperitoneum.

In this study, we chose PCV as it was found to be more appropriate for patients undergoing laparoscopic bariatric surgery rather than volume-controlled ventilation. A higher lung compliance and lower Ppeak, plateau pressure, and airway resistance were observed with PCV.[24-26] The decrease in Ppeak associated with PCV ventilation is likely to be a consequence of its decelerating inspiratory flow pattern with the maximum value reached early in inspiration with early alveolar inflation and an increase in Pmean.[26,27]

Being short of atelectasis detection is a limitation of this study. Oxygenation may be a poor indicator of the extent of lung collapse as oxygenation has not been found to correlate with atelectasis formation during Pneumoperitoneum.[5,28] Controlled studies using computed tomography to compare ERV versus PEEP are needed to reveal this issue.

For our knowledge, this is the first study to evaluate the effect of increasing I:E ratio on arterial oxygenation in laparoscopic bariatric surgery. Further studies are needed to find out the optimal increment in I:E ratio that can improve arterial oxygenation without adverse respiratory and hemodynamic effects. Also, other studies that combine ERV with recruitment maneuver and/or high PEEP are needed.

In conclusion, compared to the conventional PC-1:2 ratio, PC-ERV is more effective in increasing PaO_2, Pmean and Cdyn with significantly less Ppeak is achieved to move similar TV in laparoscopic bariatric surgery.

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