

The effect of lung recruitment maneuver on blood oxygenation in patients undergoing general anesthesia for laparoscopic surgery

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Received date: 26/02/2022

Accepted date: 13/03/2022

Published date: 15/06/2022

Abstract

Introduction: General anesthesia and laparoscopic surgery impair respiratory function followed by reduced functional residual capacity, atelectasis, and even ventilator-induced lung injury. Ventilation strategies protecting the lungs and improving oxygenation during surgery have been studied, including lung recruitment maneuvers. However, the results of studies are not consistent, so we carry out this study with the research question: "How effectively does lung recruitment maneuver impact on blood oxygenation status in laparoscopic surgery?"

Patients and methods: a RCT study on 61 patients divided into two groups: control group (30 patients) undergoing intraoperative ventilation with volume control ventilation (VCV) mode, volume tidal (VT) 8 ml/kg ideal body weight (IBW), PEEP 5 cmH₂O with no lung recruitment maneuver (LRM) and intervention group (31 patients) undergoing intraoperative ventilation with VCV mode, VT 8 ml/kg IBW, PEEP 5 cmH₂O, with lung recruitment maneuver (LRM).

Results: At the end of surgery, PaO₂ in the LRM group (258.95 ± 47.94 mmHg) was higher than that in the control group (228.93 ± 45.67 mmHg), p < 0.05; the PaO₂/FiO₂ value in the LRM group (517.90 ± 95.87 mmHg) was higher than that in the control group (457.86 ± 91.33 mmHg), p < 0.05. In the recovery room, after being extubated in 60 minutes and spontaneous breathing in 15 minutes, the PaO₂ value in the LRM group (100.87 ± 7.27 mmHg) was higher than that in the control group (88.89 ± 3.53 mmHg), p < 0.05; the PaO₂/FiO₂ value in the LRM group (480.35 ± 34.64 mmHg) was higher than that in the control group (417.30 ± 16.86 mmHg), p < 0.05; SpO₂ in the LRM group (98.22 ± 1.31%) was higher than that in the control group (97.10 ± 1.88%), p < 0.05.

Conclusion: Lung recruitment maneuver increases oxygenation in laparoscopic surgery.

Keywords: Lung recruitment maneuver, atelectasis in anesthesia, oxygenation.

Introduction

General anesthesia and mechanical ventilation are indicated for many different types of surgery. However, there are evidences that respiratory function is impaired during anesthesia and mechanical ventilation due to reduced functional residual capacity, atelectasis, and even ventilator induced lung injury[1], [2]. Many studies have been conducted to find the most effective ventilation strategies to protect the lung parenchyma during anesthesia such as low tidal volume ventilation, optimal positive end-expiratory pressure, lung recruitment maneuver... The aim of these strategies is to avoid atelectasis, and prevent hyperinflation[3]. In patients undergoing laparoscopic surgery, the risk of intraoperative atelectasis is higher due to increased intra-abdominal pressure, decreased lung volume, changes in diaphragms activity amplitude as well as surgical positions affecting ventilation and lung mechanics[4]. An growing body of evidence has demonstrated that low tidal volume ventilation play an important role in lung protective strategy in anesthetized patients, while other strategies require more research.

LRM increases airway pressure for a certain period of time with the aim of re-opening collapsed alveoli, thereby reducing shunts in the lungs, increasing the matching of ventilation and perfusion, increasing oxygenation[5]. There are many studies evaluating the effectiveness of LRM, but the results of these studies are still conflicting. In Vietnam, there are not many studies on the effectiveness of LRM in surgical patients, especially in laparoscopic surgery, so we carried out the research: "The effect of lung recruitment maneuver on blood oxygenation in patients undergoing general anesthesia for abdominal laparoscopic surgery".

Materials and methods

We performed a randomized controlled trial at Viet Duc University Hospital from March 2021 to August 2021. The trial protocol was approved by

the Medical Ethics Committee of Hanoi Medical University and Viet Duc University Hospital. Of note, written informed consent must be agreed to sign by all patients before inclusion.

Participants

Inclusion criterial: Patients older than 18 years old, who were indicated for elective abdominal laparoscopic surgery with anesthesia time was greater than 2h, classified as American Society of Anesthesiologists (ASA) physical status I- III
Exclusion criteria: Patients with chronic respiratory diseases (COPD, asthma), pneumonia, pulmonary metastases, history of lung surgery, traumatic brain injury, increased intracranial pressure, cage deformity chest and thoracic pathology, heart failure, arrhythmia and required to continue prolonged mechanical ventilation more than 4 hours after surgery.

Standard procedure

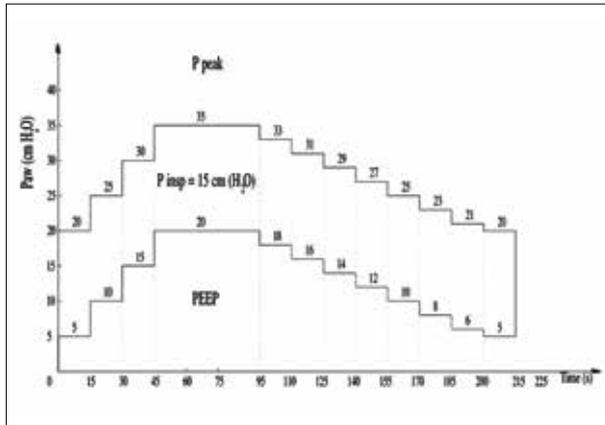
Anaesthetic management

A standardized anesthetic technique was used in both groups. The patient received an intravenous infusion of 8ml/kg of crystalloid before induction of anesthesia and 5ml/kg/h of crystalloid during surgery. Anaesthesia was induced with fentanyl 2µg/kg, propofol 1.5 - 2mg/kg, rocuronium 0.6 mg/kg and maintained with sevoflurane. Supplementary boluses of fentanyl 1µg/kg and were given intravenously as required for analgesia or esmeron 0.3 mg/kg when TOF > 20%. In addition to the standard American Society of Anesthesiologist monitors, arterial pressure was measured via a radial artery catheter in all patients.

Ventilatory management

Patients were randomized to one of the two ventilatory management strategies: Lung recruitment maneuver (group 1) and control (group 2). In all patients, mechanical ventilation was initiated immediately after tracheal intubation using volume control mode. In both groups, inspiratory to expiratory time ratio was 1:2 and inspired oxygen fraction was 0.5 at a fresh flow rate of 2 litre/min. The anesthesia machine was used in the study is

Aisys CS², from GE Healthcare. In the LRM group, lung recruitment was achieved by sequential steps as following diagram.



Lung recruitment was repeated at 30 and 60 min after abdominal inflation and 5 min after abdominal deflation. In the control group, initial ventilation was maintained until the end of surgery with PEEP 5 cmH₂O. The breath frequency was adjusted to keep end- tidal CO₂ levels at 30 – 40 mmHg. After extubation, the patient was given oxygen through a face mask at a flow rate of 5 liters/minute for one hour, then allowed the patient to breathe without oxygen supplier for 15 minutes and then took arterial blood gases and vital signs. If during the period of spontaneous breathing, the patient had SpO₂ < 94%, the value would be recorded and then return to use oxygen mask 5 liters/min. The patient underwent lung ultrasound in the recovery room to detect complications such as pneumothorax, pneumomediastinum, and subcutaneous pneumothorax.

Measurements

Arterial blood gases were corrected for body temperature and were determined at the following time intervals: K1: before induction, K2: at the end of surgery, K3 in the post- anaesthesia unit after extubation 60 min and spontaneous breathing for 15 minutes.

Arterial blood gas analysis was performed on Stat Profile Prime Plus blood gas analyzer (Nova

Biomedical, USA). The blood gas analyzer was calibrated daily. Lung ultrasound was performed to detect postoperative pneumothorax complications.

Statistical analysis: statistical procedures were performed using SPSS statistical package version 20.0

Results

Table 1. Age, height, weight, BMI

Index	Group	LRM (n = 31)	Control (n = 30)	p
		$\bar{X} \pm SD$ (Min – Max)	$\bar{X} \pm SD$ (Min – Max)	
Age (year)		51,48 ± 14,02 (26 - 83)	53,30 ± 12,43 (31 - 80)	> 0,05
Weight (kg)		57,06 ± 5,94 (45 - 69)	56,63 ± 5,68 (48 - 70)	> 0,05
Height (cm)		162,42 ± 5,72 (150 - 176)	159,23 ± 7,2 (147 - 175)	> 0,05
BMI (kg/m ²)		21,61 ± 1,76 (17,93 - 24,74)	22,33 ± 1,57 (18,75 - 24,71)	> 0,05
Ideal body weight (kg)		56,92 ± 5,23 (47,8 - 66,9)	54,54 ± 7,40 (43,2 - 70,6)	> 0,05

Comment: There had no significant differences between age, weight, height, BMI and ideal body weight index between 2 groups with p > 0.05

Table 2. Health status according to ASA classification

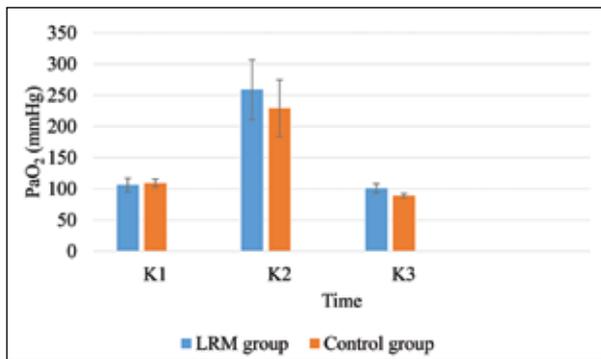
ASA	Group	LRM (n = 31)	Control (n = 30)	p		
		N	%		N	%
I		18	58,1	20	66,7	
II		12	38,7	10	33,3	> 0,05
III		1	3,2	0	0	

Comment: There had no significant difference between ASA classification between 2 groups with p > 0.05.

Table 3. Surgical and anesthesia time (minute) in two groups

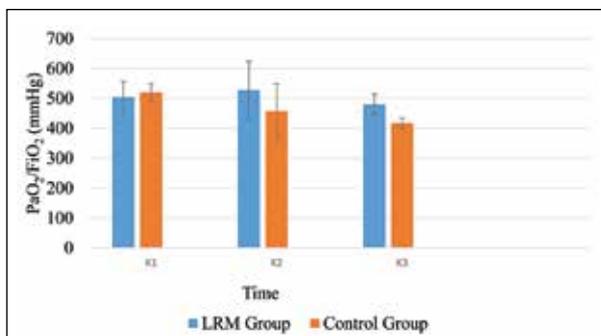
Group	LRM (n = 31)	Control (n = 30)	p
	$\bar{X} \pm SD$ (Min - Max)	$\bar{X} \pm SD$ (Min - Max)	
Surgery	206,29 ± 39,26 (120 - 300)	208,17 ± 39,47 (130 - 290)	> 0,05
Anesthesia	224,35 ± 39,02 (140 - 315)	227,33 ± 38,97 (150 - 310)	> 0,05

Comment : There had no significant differences between surgery and anesthesia time between two groups with $p > 0.05$.



Graph 1: PaO₂ values of the two groups

Comment: PaO₂ at the time K1 was similar between the two groups, $p > 0.05$. At the time K2 and K3, PaO₂ in the LRM group was higher than the control group, $p < 0.05$.



Graph 2: PaO₂/FiO₂ values of the two groups

Comment: At the time K1, PaO₂/FiO₂ of two groups is equivalent, $p > 0.05$. At the time K2 and K3, PaO₂/FiO₂ of LRM groups is higher than control group with $p < 0.05$.

Table 4: SpO₂ values of the two groups

Group	LRM (n = 31)	Control (n = 30)	p
	$\bar{X} \pm SD$ (Min - Max)	$\bar{X} \pm SD$ (Min - Max)	
Before induction	98,87 ± 1,09 (97 - 100)	98,60 ± 1,13 (97 - 100)	> 0,05
10 minutes after induction	99,74 ± 0,44 (99 - 100)	99,70 ± 0,22 (99 - 100)	> 0,05
At the end of surgery	99,70 ± 0,47 (99 - 100)	99,65 ± 0,49 (99 - 100)	> 0,05
At recovery room	98,22 ± 1,31 (94 - 100)	97,10 ± 1,88 (93 - 99)	< 0,05

Before induction, PaO₂ index and the PaO₂/FiO₂ ratio of the two groups were similar. At the end of surgery and after extubation, PaO₂ index and the PaO₂/FiO₂ ratio in the LRM group was significantly higher than the control group with $p < 0.05$. Before induction and during surgery, SpO₂ was similar between two group, $p > 0.05$. At recovery room, after extubation, patients breath O₂ mask 5 liters/minute in 60 minutes and breathing air room in 15 minutes, SpO₂ of the LRM group was 98.22 ± 1.31% higher than that of the control group of 97.10 ± 1.88% with $p < 0.05$ (table 4).

Discussions

The lung recruitment maneuvers increased arterial oxygenation during general anaesthesia. The recruitment method we used in this study was a modification of that described by Tusman et al[6]. To standardize the lung recruit maneuver, we used anesthesia ventilator to gradually increase the levels of PEEP to open alveoli for a certain amount of time Although we did not directly measure recruited lung volume, the significant increase in PaO₂ produced by recruitment maneuver presumably was caused by decreased atelectasis. Treatment with PEEP 5 cmH₂O alone, did not have the same effect on oxygenation.

A variety of studies have reported that administration of PEEP combined with the recruitment maneuver ensures better oxygenation

compared to patients with only PEEP applied[5], [7]. The increase in arterial oxygenation after the recruitment maneuver suggested a reversal of anesthesia induced atelectatic and the ventilation/perfusion inhomogeneity. This finding was compatible with the results of Hedenstierna et al[3]. Sumer et al[8] performed LRM for the intervention group once after abdominal deflation, the author found that PaO₂ value after induction of the two groups was similar, 10 minutes after abdominal inflation, PaO₂ value in the LRM group was lower than that in the control group, but after lung recruitment, PaO₂ increased in the lung recruitment group (166.2 mmHg to 211.5 mmHg) while in the control group PaO₂ remained unchanged. Nguyen Trung Kien[9] and Lai Van Hoan[10] found that, at the end of surgery and 1 hour after extubation, the PaO₂ value of the LRM group was significantly higher than that of the control group. Aretha et al[11] found that, SpO₂ of LRM group was higher than that of the control group at all times after lung recruitment and lasted until 20 minutes after the end of surgery. Liu et al[12] monitored SpO₂ at the day 2nd and 5th after surgery and found that with lung recruitment maneuver and PEEP 10 cmH₂O, SpO₂ was higher than that in group with no lung recruitment and PEEP 0 cmH₂O. In our study, in the control group, there were four patients had SpO₂ below 94% after 15 min spontaneous breathing while in the LRM group, there was only 1 patient.

Although we intentionally applied high airway pressures, no patient showed evidence of barotrauma on lung ultrasound after surgery. In our study, the use of vasopressors and the number of patients required to use vasopressor was similar between two groups. Nielson et al[13] evaluated the effect of the lung recruitment on central hemodynamics in situations with hypovolemia, normovolemia, and hypervolemia. They found that during hypovolemia, left ventricular end-diastolic volume and cardiac output significantly decreased, while hypervolemia prevented these effects. In our study, we administered IV fluid before induction

and during surgery, thus our patients could avoid hypovolemia. However, 2 patients in LRM group who had blood pressure were below 20% of baseline during lung recruitments. These two patients, after volume compensation according to the study protocol, during the surgery and the subsequent lung recruitment maneuver, we did not find any complications of hypotension.

Based on the findings obtained in our study, we believe the recruitment maneuvers undergoing laparoscopic surgery is an effective method to increase blood oxygenation and can be used safely.

Conclusions

Our study shows that the alveolar maneuver increased blood oxygenation in patients under general anesthesia during laparoscopic surgery. The blood oxygenation values in the alveolar maneuver group were higher than that of control group at the end of surgery and constant until the time after the patient was extubated.

Conflict of interest: The authors declare that they have no conflict of interest.

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