Effect of positive end-expiratory pressure on pulmonary compliance and pulmonary complications in patients undergoing robot-assisted laparoscopic radical prostatectomy: a double-blind randomized control trial

LIFENG NI
First Affiliated Hospital Zhejiang University
Menglan Chen
First Affiliated Hospital Zhejiang University
Ling'er Huang
First Affiliated Hospital Zhejiang University
Kuirong Wang
First Affiliated Hospital Zhejiang University
Yanfeng Zhou (zhouyf11@zju.edu.cn)
First Affiliated Hospital Zhejiang University

Research Article

Keywords: Robot-assisted laparoscopic radical prostatectomy, Pulmonary compliance, Positive end-expiratory pressure

Posted Date: April 20th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1431350/v2

Abstract

Purpose: To observe the effects of different levels of positive end-expiratory pressure (PEEP) ventilation strategies on pulmonary compliance and complications in patients undergoing robotic-assisted laparoscopic prostate surgery.

Methods: A total of 120 patients with American Society of Anesthesiologists Physical Status Class I or II who underwent elective robotic-assisted laparoscopic prostatectomy were enrolled. The patients were randomly divided into three groups of 40 patients each: control (PEEP=0 cmH_2O), low-level (PEEP=5 cmH_2O), and high-level (PEEP=10 cmH_2O). Volume control ventilation with an intraoperative deep muscle relaxation strategy was used intraoperatively. Respiratory mechanics indexes were recorded at six time points: 10 min after anesthesia induction, immediately after pneumoperitoneum establishment, 30 min, 1 h, 1.5 h, and at the end of pneumoperitoneum (T1-T6). Arterial blood gas analysis and oxygenation index calculation were performed at T1, T4, and after tracheal extubation (T7). Postoperative pulmonary complications were also recorded.

Results: After pneumoperitoneum, peak inspiratory pressure (Ppeak), plateau pressure (Pplat), mean pressure (Pmean), driving pressure (ΔP), and airway resistance (Raw) increased significantly and pulmonary compliance (Crs) decreased, persisting during pneumoperitoneum in all groups. Between T2–T5, Pulmonary compliance in Group high-level was higher compared with Groups low-level (53.7/39.2/37.2/35.8 vs. 46/33.6/33.7/32.5; P<0.05) and control (53.7/39.2/37.2/35.8 vs. 38.4/28.2/26.7/27.4; P<0.05) .The driving pressure (ΔP) at T2–T5 in Group high-level was lower compared with Groups low-level (9.7/13.2/13.8/14.3 vs. 12.3/16.0/16.2/17.3; P<0.05) and control (9.7/13.2/13.8/14.3 vs. 17.0/21/22.3/22.0; P<0.05).

At T4 and T7, the PaCO2 and PaO2/FiO2 did not significantly differ among the three groups((P0.05). There was no significant difference in postoperative pulmonary complications among the three groups(P0.05).

Conclusion: High levels of intraoperative PEEP increased lung compliance without significantly reducing postoperative pulmonary complications.

RegisteredThe study was registered in the China Clinical Trials Registry 30/05/ 2020 (Registration No. ChiCTR2000033380).

1. Background

The International Agency for Research in Oncology (IARC) estimated 1,414,259 new cases of prostate cancer and approximately 375,304 prostate-cancer-related deaths worldwide in 2020 [1]. With the continuous advancement of minimally invasive surgery and the rapid development of artificial intelligence-assisted systems, an increasing number of studies have shown that robotic-assisted laparoscopic radical prostatectomy (RARP) is superior to traditional open radical prostatectomy or pure laparoscopic radical prostatectomy in aspects such as in providing a clearer field, a more delicate operation execution, less trauma, less blood loss, and complete radical treatment [2]. While the da Vinci robot-assisted surgery has benefited prostate cancer patients, the anesthetic management of patients undergoing RARP surgery, especially managing the physiological changes due to pneumoperitoneum and a steep head-down position, has become one of the main recent topics in anesthesiology [3,4]. The establishment of pneumoperitoneum and head-down position can cause serious interference with pulmonary function: first, it affects diaphragm elevation, causing decreased thoracopulmonary compliance, reduced functional residual air volume, and pulmonary atelectasis. This increases the possibility of hypoxemia. Ventilation pressure increases significantly as well, which may damage the lungs and increase the occurrence of postoperative pulmonary complications. Pulmonary complications occur in about 5% of patients undergoing surgical procedures under general anesthesia with tracheal intubation, leading to prolonged postoperative recovery and increased hospital costs [5]. There are many causes of postoperative pulmonary complications, including barotrauma during general anesthesia [4,5]. Therefore, the anesthetic management of perioperative pulmonary protection is an important component for rapid patient recovery. Pulmonary protective ventilation, which combines a low tidal volume (6-8 mL/kg) and positive end-expiratory pressure (PEEP) ventilation, was initially used in patients with respiratory distress syndrome and is now considered beneficial in "normal lung" patients under general anesthesia with tracheal intubation [5,6]. For laparoscopic procedures requiring CO_2 pneumoperitoneum, a "permissive hypercapnia," where small tidal volume ventilation is applied and the arterial blood CO_2 partial pressure is allowed to reach ≥60-70 mmHg for a short period, was proposed to avoid lung damage from high ventilation pressure [6]. In a study of 40 cases of patients who underwent elective abdominal surgery with individual PEEP value monitoring by thoracic image scanning, a PEEP of 6-16 cmH_2O with a median of 12 cmH_2O is required to improve pulmonary compliance and reduce pulmonary atelectasis [7]. It has also been suggested that high PEEP levels (10 cmH_2O) significantly improve lung compliance and reduce the incidence of atelectasis during mechanical ventilation compared to low PEEP levels and no PEEP ventilation [8,9].

Most anesthetized patients treated with RARP surgery have a healthy level of pulmonary function with good lung compliance. There is a lack of systematic studies on whether intraoperative PEEP is needed to improve oxygenation and reduce postoperative pulmonary complications in this group. It is important to guide clinical anesthesiologists in managing respiratory function of patients undergoing RARP surgery with safer and more effective mechanical ventilation parameters by finding the appropriate PEEP values. In this study, we investigated the feasibility of a PEEP ventilation strategy in patients undergoing RARP surgery and its effects on ventilation, oxygenation, and postoperative rehabilitation.

2. Patients And Methods

This prospective randomized double-blind controlled trial was reviewed and approved by the IIT Ethics Review Panel of the Clinical Research Ethics Committee of the First Hospital of Zhejiang University School of Medicine on 06/05/2020 (Session No. 48). The study was registered in the China Clinical Trials Registryon(Registration No. ChiCTR2000033380).

Clinical research manuscripts that comply with the Declaration of Helsinki and relevant Governmental regulation .Studies which are adequately controlled , blinded, randomised and of sufficient statistical power to confidentially and accurately interpret the effect reported.

2.1. Patients

Written informed consent was obtained from all subjects. The inclusion criteria were ASA classification I-II and no history of serious systemic disease. Exclusion criteria were age >80 years, history of severe cardiopulmonary, hepatic, and renal disease, history of neuromuscular disease, excessive obesity or malnutrition (body mass index, BMI ≥ 30 or ≤ 20), history of drug allergy, etc. Using SPSS 23 (IBM, Armonk, NY, USA), patients were randomly allocated to three groups (40 patients per group): control group (group A: PEEP=0), low-level PEEP group (group B: 5 cmH_2O), and high-level PEEP group (group C: 10 cmH_2O). Randomization was performed by a researcher not involved in the anesthesia or statistical analysis. The attending anesthetist was given an envelope containing the allocation results. The patient, the surgeon, and the resident anesthetist responsible for the records were blinded to the PEEP level. A flowchart of the study is shown in Figure 1.

2.2. Anesthesia method

After the patient was admitted to the operating room, an invasive arterial puncture was performed in addition to routine monitoring and preoperative blood gas analysis. Induction of anesthesia took place through intravenous administration of etomidate, fentanyl, rocuronium bromide 0.6 mg/kg, followed by tracheal intubation and mechanical ventilation. Ventilation was set to volume-controlled breathing (60% oxygen concentration, mixed air) with an initial tidal volume of 7 mL/kg and a frequency of 12 breaths/min. The PEEP was set to 0, 5, and 10 cmH_2O according to the grouping. The parameters were adjusted before pneumoperitoneum to maintain an end-expiratory carbon dioxide partial pressure of 30–35 mmHg. When end-expiratory carbon dioxide reached ≥60 mmHg (expected blood carbon dioxide partial pressure of 70 mmHg), hypercapnia was permissive during pneumoperitoneum to increase respiratory rate at first. If end-expiratory carbon dioxide could not be reduced or continued to rise, hypercapnia can continue to increase tidal volume when. No pulmonary resuscitation strategy was used for any ventilation mode. Intraoperative rocuronium bromide 0.6 mg/kg/h was pumped intravenously to maintain deep muscular relaxation at 0 train of four (TOF) stimulation response and 1-2 post tonic counts (PTC). Rocuronium was discontinued at the end of pneumoperitoneum.

2.3. Monitoring

Pulse oximetry, electrocardiogram (ECG), temperature measurement, bispectral index (BIS) monitoring, invasive arterial pressure monitoring, end-expiratory carbon dioxide measurement, pressure-volume loop measurement, accelerometer monitoring of muscle relaxation, and blood gas analysis were performed. Data were recorded for patients in all groups at six time points: after induction (T1), pneumoperitoneum establishment (T2), 0.5 h after pneumoperitoneum (T3), 1 h after pneumoperitoneum (T4), 1.5 h after pneumoperitoneum (T5), and at the end of pneumoperitoneum (T6). Data obtained include tidal volume, respiratory rate, end-expiratory carbon dioxide partial pressure, peak airway pressure, plateau pressure, lung compliance, airway resistance, pulse oximeter, blood pressure, heart rate, duration of surgery, among others. Blood gas analysis was performed after anesthesia induction, 1 h after pneumoperitoneum, and after tracheal extubation. Follow-up visits were performed on postoperative days 1, 3, and one month after surgery. Indicators for postoperative pain and postoperative complications were monitored and recorded.

2.4. Statistical Analysis

The Kolmogorov-Smirnov test was used to test the normality of the distributions of all variables. The values of peak inspiratory pressure (Ppeak), mean pressure (Pmean), pulmonary compliance (Crs), airway resistance (Raw),partial pressure of carbon dioxide in artery ($PaCO_2$) and ratio of partial pressure of O2 in arterial blood to fraction of inspired oxygen (PaO_2/FiO_2) at different timepoints are expressed as median and interquartile ranges, where the data were not normally distributed. Patient characteristics, time to pneumoperitoneum, time to surgery, and time to extubation were expressed as median and interquartile ranges. Differences between multiple time points were analyzed using Kruskal-Wallis and one-way analysis of variance (ANOVA) post hoc tests. The Mann–Whitney U test was used to analyze the differences between two time points and groups. $\chi 2$ tests were used to compare the number of patients with agitation upon awakening and that of those with postoperative pulmonary complications in all groups.

To determine the sample size, a pretest was performed. The mean Crs during pneumoperitoneum (Pnp) of 0, 5, 10 cmH_2O of PEEP were 27 mL/cmH_2O, 32 mL/cmH_2O, and 34 mL/cmH_2O with standard deviations of 7, 9, and 10, respectively. Considering P value = 0.05 and a degree of certainty of 0.90, to distinguish the Crs of each group, at least 28 patients were required per group.

3. Results

Patient characteristics such as height, weight, age, BMI, pneumoperitoneum time, and operative time (Table 1) were not significantly different among groups.

After establishment of the pneumoperitoneum, Peak, Pmean, Raw, Plat, and ΔP (driving pressure) increased while Crs decreased(Supplementary Table 1.2.3). These changes persisted during pneumoperitoneum in all groups. At the end of the pneumoperitoneum, these indices improved but did not return to post-induction levels (Table 1). At T2, T3, T4, and T5, the 10 cmH_2O PEEP group had the highest Crs ($P<0.05$) and the smallest ΔP values ($P<0.05$) relative to the other groups (Figure 2). During T2–T5, there was no significant difference in Peak, Mean, and Raw between the 0 and 5 cmH_2O PEEP groups ($P>0.05$). At T1, T4, and T7, there was no significant difference in $PaCO_2$ and PaO_2 among groups ($P>0.05$, Table 2). There was no difference in SpO_2 and VAS scores or in the rate of pulmonary complications at 1 and 3 post-operative days ($P>0.05$, Figure 3, Table 3). Extubation and PACU times were significantly longer in the 5 cmH_2O PEEP group ($P<0.05$), but there was no significant difference in agitation during the awakening period and hospital stay among groups ($P> 0.05$, Table 4).

4. Discussion

Laparoscopic patients under general anesthesia are prone to pulmonary atelectasis and postoperative pulmonary complications after mechanical ventilation [10,11]. In RARP, the incidence of atelectasis often increases due to the patient's older age and the surgical position . To obtain the best surgical view, RARP requires a Trendelenburg position >30˚, with intra-abdominal organs compressing the diaphragm and lungs. In addition, the elderly tend to have poor lung compliance and a higher incidence of postoperative pulmonary atelectasis compared to younger patients [12,13]. Furthermore, our previous study showed that use of deep neuromuscular blockade during RARP did not increase pulmonary compliance and reduce pulmonary complications [14].

We used continuous dynamic pulmonary respiratory mechanics monitoring and found that the establishment of pneumoperitoneum and the change in surgical position decreased pulmonary compliance in patients, which is consistent with the results of related studies [15]. This may be due to a decrease in pulmonary compliance caused by diaphragmatic elevation, restricted thoracic motion due to pneumoperitoneal pressure, and the effect of gravity in the Trendelenburg position, which increases pulmonary stasis, further disturbing pulmonary ventilation/flow ratio. Patients administered either 5 cmH_2O or 10 cmH_2O in this study showed an increase in lung compliance, presumably because a certain PEEP level counteracts the effects of manual pneumoperitoneum and the Trendelenburg position on lung compliance in RARP patients. These results are consistent with current clinical findings [16]. Most studies on intraoperative protective mechanical ventilation have not individualized the PEEP level applied. An arbitrary selection of PEEP levels in different patient populations and surgical approaches can lead to heterogeneity of results [17]. The choice of PEEP level should be based on the patient’s characteristics, the specific surgical access site, and the patient's position [18]. In a study of obese patients undergoing laparoscopic bariatric surgery, the use of an individualized stepwise PEEP approach with lung ultrasound improved lung compliance and oxygenation [19].

In addition, the present study observed that 10 cm H_2O PEEP did not significantly improve the key intraoperative oxygenation index nor significantly reduce the incidence of postoperative pulmonary complications, showing a limited protective effect on the lungs. Similarly, Van Hecke et al. reported that in laparoscopic bariatric surgery, optimizing lung compliance by PEEP did not reduce the incidence of postoperative hypoxemia [20]. In contrast, combining pulmonary resuscitation strategies with PEEP significantly reduced perioperative pulmonary complications compared with PEEP alone in elderly patients undergoing RARP [21]. We hypothesized that appropriate PEEP can increase end-expiratory alveolar volume, reduce intrapulmonary shunts, increase lung compliance, and improve oxygenation. However, an inappropriately high PEEP results in higher airway and plateau pressures, which may produce hyperbaric lung injury [22]. An excessively high PEEP level increases thoracic pressure, which can significantly affect right ventricular outflow resistance [23], in turn can cause an imbalance in ventilatory flow ratio. Future studies should investigate and implement lung-protective low ventilation strategies with electrical impedance tomography (EIT) of the chest or lung ultrasound to help determine the appropriate PEEP values.

This study also has limitations: First, postoperative pulmonary function and lung CT monitoring, which can help evaluate the incidence of pulmonary complications accurately, were not performed. Second, intraoperative cardiac output values, which would allow to understand the effect of different PEEP values on hemodynamics, were not recorded. Third, we did not individualize PEEP settings [24]. The use of individualized titrated PEEP setting for perioperative lung protection may be a trend in the future.

5. Conclusion

Applying a high-level PEEP (10 cmH_2O) in robotic-assisted laparoscopic prostatectomy under deep muscle relaxation increased lung compliance and decreased driving pressure values after pneumoperitoneum. However, it did not improve oxygenation 1 h after pneumoperitoneum nor did it significantly reduce postoperative pulmonary complications. Individualized pulmonary protective ventilation strategies are needed in the future.

Abbreviations

PEEP, positive end-expiratory pressure; Ppeak, peak inspiratory pressure; Pplat, plateau pressure; Pmean, mean pressure; ΔP, driving pressure; Raw, airway resistance; Crs, pulmonary compliance; $PaCO_2$, partial pressure of carbon dioxide; PaO_2, partial pressure of oxygen

Declarations

Ethics approval and consent to participate: This prospective randomized double-blind controlled trial was reviewed and approved by the IIT Ethics Review Panel of the Clinical Research Ethics Committee of the First Hospital of Zhejiang University School of Medicine on 06/05/2020 (Session No. 48). The study was registered in the China Clinical Trials Registry The study was registered in the China Clinical Trials Registry on 30/05/2020 (Registration No.ChiCTR2000033380).Written informed consent was obtained from all subjects.

Consent for publication:Not applicable

Availability of data and materials: All data generated or analysed during this study are included in its supplementary information files.

Competing interests: The authors have no relevant financial or non-financial interests to disclose

Funding: The authorsdeclare that no funds, grants, or other support were received during the preparation of this manuscript.

Authors' contributions: All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Lifeng Ni , Menglan Chen and Ling'er Huang. The first draft of the manuscript was written by Lifeng . All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Acknowledgements: Not Appilicable

Authors' information : The names of the authors:Lifeng Ni , Menglan Chen , Ling'er Huang,Kuirong Wang Yanfeng Zhou*.The affiliations of the authors:Department of Anesthesiology, The First Affiliated Hospital, College of Medicine, Zhejiang University, Hangzhou, Zhejiang, PR China.

References

1. Ferlay J, Colombet M, Soerjomataram I, et al. Cancer statistics for the year 2020: an overview[J]. International Journal of Cancer, 2021.
2. Basiri A, de la Rosette JJ, Tabatabaei S, Woo HH, Laguna MP, Shemshaki H. Comparison of retropubic, laparoscopic and robotic radical prostatectomy: who is the winner? World J Urol 2018; 36(4): 609-21.
3. Shono A, Katayama N, Fujihara T, et al. Positive End-expiratory Pressure and Distribution of Ventilation in Pneumoperitoneum Combined with Steep Trendelenburg Position. Anesthesiology 2020; 132(3): 476-90.
4. Atkinson TM, Giraud GD, Togioka BM, Jones DB, Cigarroa JE.Cardiovascular and Ventilatory Consequences of Laparoscopic Surgery. Circulation 2017; 135(7): 700-10.
5. Gü ldner A, Kiss T, Serpa Neto A, et al. Intraoperative Protective Mechanical Ventilation for Prevention of Postoperative Pulmonary Complications: A Comprehensive Review of the Role of Tidal Volume, Positive End-expiratory Pressure, and Lung Recruitment Maneuvers. Anesthesiology 2015; 123: 692-713.
6. Park SJ, Kim BG, Oh AH, Han SH, Han HS, Ryu JH. Effects of intraoperative protective lung ventilation on postoperative pulmonary complications in patients with laparoscopic surgery: prospective, randomized and controlled trial. Surg Endosc 2016; 30(10): 4598-606.
7. Pereira SM, Tucci MR, Morais CCA, et al. Individual Positive End-expiratory Pressure Settings Optimize Intraoperative Mechanical Ventilation and ReducePostoperative Atelectasis. Anesthesiology 2018; 129(6): 1070-81.
8. Spadaro S, Karbing DS, Mauri T, et al. Effect of positive end-expiratory pressure on pulmonary shunt and dynamic compliance during abdominal surgery. Br J Anaesth 2016; 116(6): 855-61
9. Deng QW, Tan WC, Zhao BC, Wen SH, Shen JT, Xu M. Intraoperative ventilation strategies to prevent postoperative pulmonary complications: a network meta-analysis of randomised controlled trials. Br J Anaesth 2020; 124(3): 324-35.
10. Gunnarsson L, Tokics L, Gustavsson H, Hedenstierna G. Influence of age on atelectasis formation and gas exchange impairment during general anaesthesia. Br J Anaesth 1991; 66(4): 423–432. PMID: 2025468
11. Hedenstierna G, Rothen HU. Atelectasisformation during anaesthesia: causesand measures to pre-vent it. J Clin Monit Comput 2000; 16(5–6): 329–335. PMID:12580216
12. Ince M E , Ozkan G , Ors N, et al. Anesthesia management for robotic assisted radical prostatectomy. Single center experince[J]. 2020.
13. Brandão JC, Lessa MA, Motta-Ribeiro G, et al., 2019. Global and regional respiratory mechanics during robotic-assisted laparoscopic surgery: a randomized study. Anesth Analg, 129(6):1564-157315

14. Zhu S J, Zhang X L, Xie Q, et al. Comparison of the effects of deep and moderate neuromuscular block on respiratory system compliance and surgical space conditions during robot-assisted laparoscopic radical prostatectomy: a randomized clinical study[J]. Journal of Zhejiang University-SCIENCE B, 2020, 21(8):637-645.
15. Eddie Wang, Wang Zhaomin, Zhang Ying, et al. Effects of different levels of positive end-expiratory pressure ventilation on pulmonary compliance and pulmonary oxygenation in patients undergoing head-down laparoscopy[J]. International Journal of Anesthesiology and Resuscitation, 2017(2).
16. Tusman G, Böhm SH, Vazquez de Anda GF, do Campo JL, Lach-mann B.Alveolar recruitment strategy improves arterial oxy-genation during general anaesthesia. Br J Anaesth. 1999;82:–13.
17. Kacmarek RM, Villar J. Lung-protective ventilation in the operating room:individualized positive end-expiratory pressure is needed! Anesthesiology.2018;129(6):1057–9.
18. Ferrando C, Mugarra A, Gutierrez A, Carbonell JA, Garcia M, Soro M, et al.Setting individualized positive end-expiratory pressure level with a positiveend-expiratory pressure decrement trial after a recruitment maneuverimproves oxygenation and lung mechanics during one-lung ventilation.Anesth Analg. 2014;118(3):657–65
19. EMD Mohamed, Khair T , Marina B , et al. The use of intraoperative bedside lung ultrasound in optimizing positive end expiratory pressure in obese patients undergoing laparoscopic bariatric surgeries - ScienceDirect[J]. Surgery for Obesity and Related Diseases, 2020.
20. Delphine, Hecke V , Javad S , et al. Does Lung Compliance Optimization Through PEEP Manipulations Reduce the Incidence of Postoperative Hypoxemia in Laparoscopic Bariatric Surgery? A Randomized Trial.[J]. Obesity surgery, 2019.
21. Eun-Su C , Ah-Young O , Chi-Bum I , et al. Effects of recruitment manoeuvre on perioperative pulmonary complications in patients undergoing robotic assisted radical prostatectomy: A randomised single-blinded trial[J]. Plos One, 2017, 12(9):e0183311.
22. Luecke T , Pelosi P , Quintel M . [Haemodynamic effects of mechanical ventilation][J]. Der Anaesthesist, 2008, 56(12):1242-1251.
23. Schmitt J M , Vieillard-Baron A , Augarde R, et al. Positive end-expiratory pressure titration in acute respiratory distress syndrome patients: impact on right ventricular outflow impedance evaluated by pulmonary artery Doppler flow velocity measurements.[J]. Critical Care Medicine, 2001, 29(6):1154-1158.
24. Pereira SM, Tucci MR, Morais CCA, et al., 2018. Individual positive end-expiratory pressure settings optimize intraoperative mechanical ventilation and reduce postoper-ativeatelectasis. Anesthesiology, 129(6):1070-1081

Tables

Table 1 Basic patient characteristics

PEEP (cmH2O)	0 cmH_2O	5 cmH_2O	10 cmH_2O	P-value
N	27	33	29	
Age (years)	65 (60-72)	70 (65-73)	69 (63-72)	0.063
Body weight (kg)	69 (65-71)	66 (61-71)	66 (61-70)	0.592
Height (cm)	170(165-172)	170 (165-171)	170 (165-173)	0.839
BMI (kg/m2)	24 (23-26)	24 (22-25)	23 (22-25)	0.446
Surgery time(min)	157(144-174)	159 (128-176)	150 (130-172)	0.514

Data are expressed as median (interquartile range)

Table 2 Arterial blood gas variables at different time points

	$PaCO_2$(mmHg)			PaO_2/FiO_2(mmHg)		
	0cmH_2OPEEP	5cmH_2OPEEP	10cmH_2OPEEP	0cmH_2OPEEP	5cmH_2OPEEP	10cmH_2OPEEP
T1	40.9（37.9-44）	41.1（39.3-42.5）	41.9（39.7-44.5）	463（367-532）	480（407-530）	440（355-503）
T4	51.1（48.2-74.5）	56.1（51.9-59.9）	54.7（46.4-57.9）	435（335-504）	422（330-475）	403（340-483）
T7	44.9（42.8-47）	46.7（45-49）	44.7（41.5-47.1）	292（245-423）	363（227-305）	262（231-355）

Data are expressed as median (interquartile range). t1: induction of anesthesia; t4: one hour after pneumoperitoneum; t7: after tracheal extubation.

Table 3 Pulmonary complications on the first and third postoperative days

One day after surgery					Three days after surgery			
	0cmH_2O PEEP	5cmH_2O PEEP	10cmH_2O PEEP	p	0cmH_2O PEEP	5cmH_2O PEEP	10cmH_2O PEEP	p
Cough（n）	24(85.7%)	23(76.6%)	21(72.4%)	0.349	19(70.3%)	19(57.5%)	12(41.3%)	0.234
Secretions（n）	10(37.0%)	11(33.3%)	10(34.4%)	0.775	4(14.8%)	9(27.2%)	6(20.6%)	0.220
Shortness of breath (n)	3(11.1%)	8(24.2%)	5(17.2%)	0.416	1(3.7%)	3(9.1%)	4(13.7)	0.419
Fever（n）	3(11.1%)	6(18.8%)	4(13.7%)	0.734	0	2(6.1%)	1(3.4%)	0.433

Data are number of patients (percentage). PEEP: positive end-expiratory pressure.

Table 4 Postoperative indicators

	0cmH_2OPEEP	5cmH_2OPEEP	10cmH_2OPEEP	p
Time of extubation(min)	35(22-48.5)	50.5(35-66.5)	39(20-57.5)	0.019
Time in PACU(min)	74(62-86.5)	92(76-112.5)	74(55-90)	0.02
Restlessness during the awakening period(n)	4	6	4	0.865
Length of hospitalization(day)	7(7-8)	7(7-8)	7(6-8)	0.863

Data are expressed as median (interquartile range) or number of patients; PEEP: positive end-expiratory pressure.

Figures

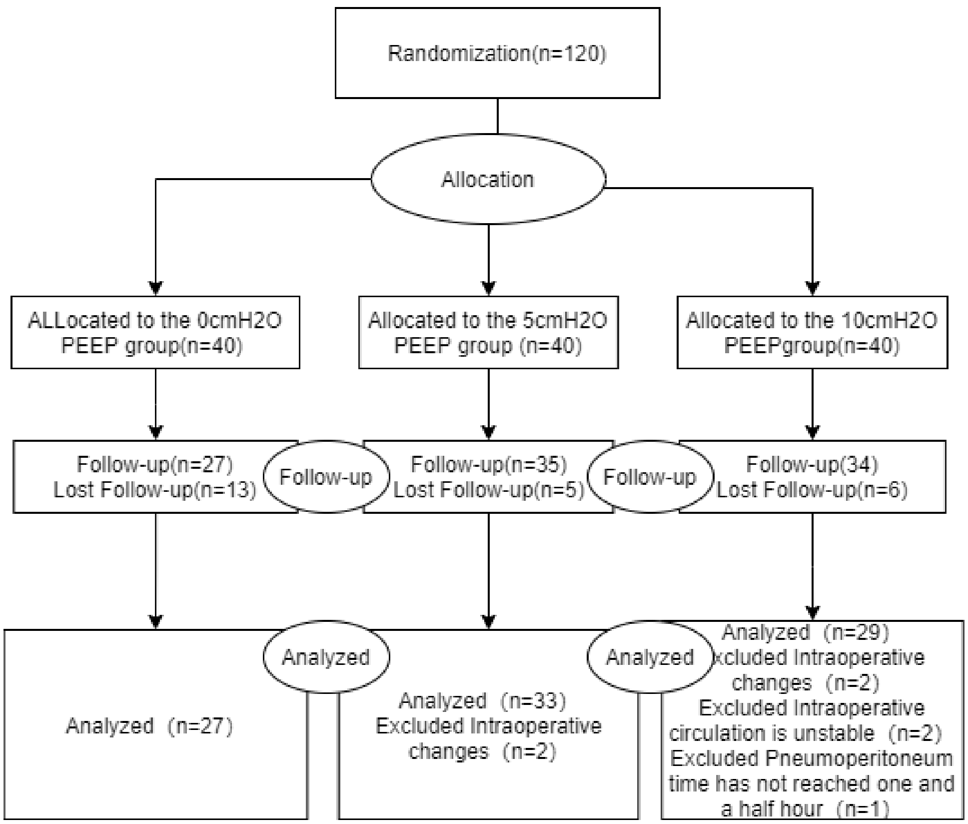

Figure 1

Experimental flow chart

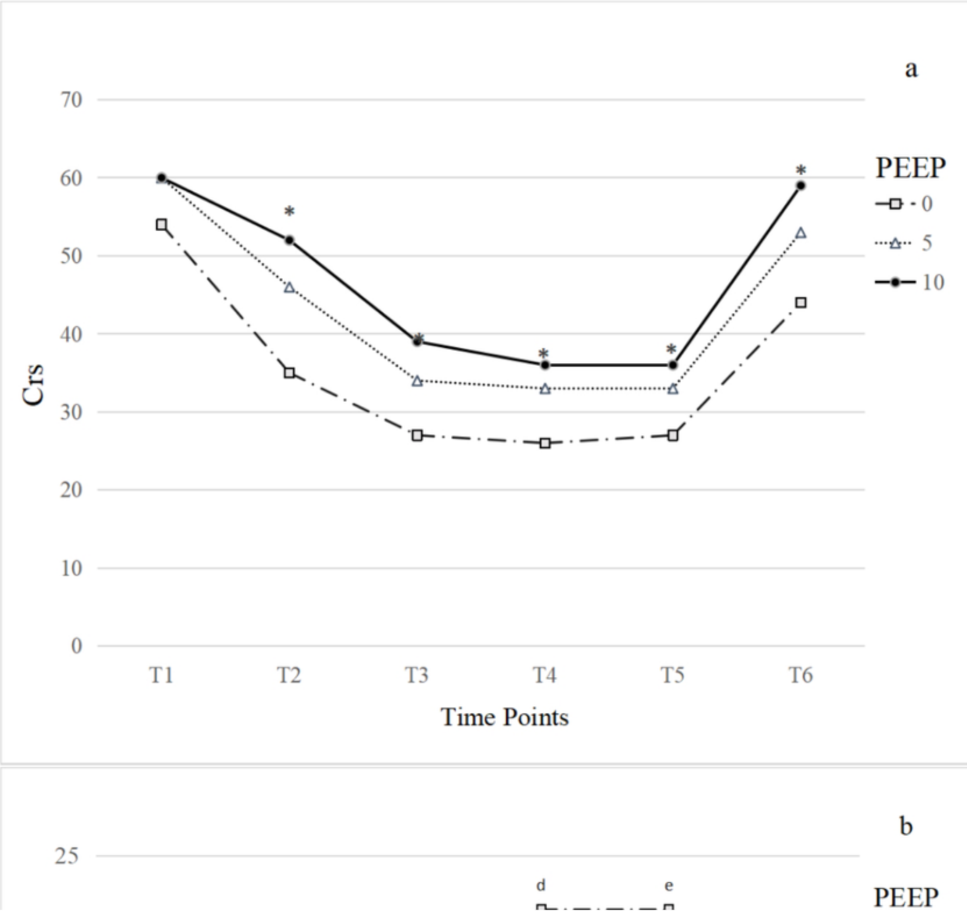

Figure 2

Respiratory mechanics at different time points during surgery

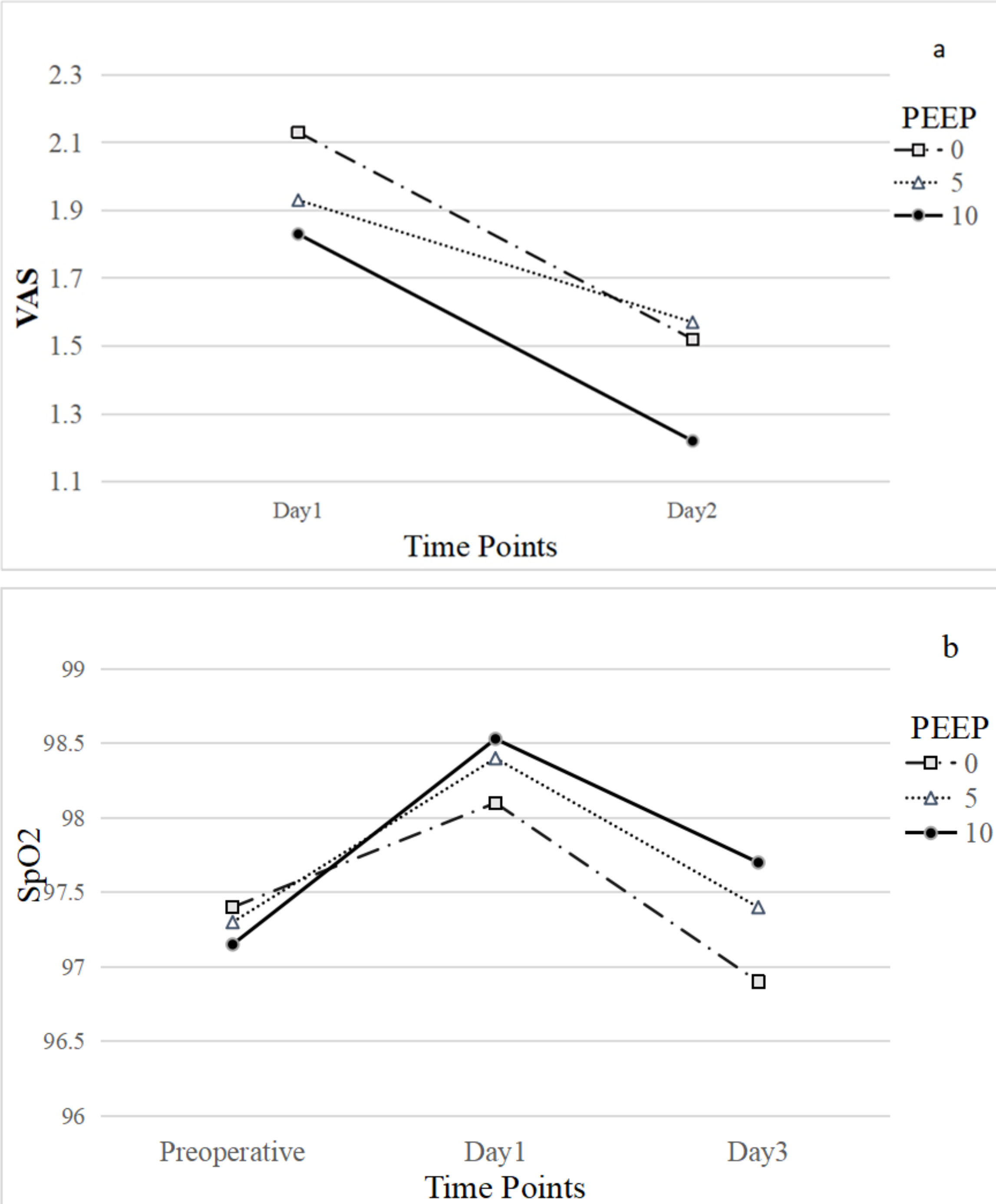

Figure 3

SpO_2 and VAS scores of the three groups at one and three days postoperatively

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.docx