JOURNAL CLUB

R3 Pakvipa Suthiyuth
Col. Siriluk Chumnanvej

ANESTHESIOLOGY

Pressure Support *versus* Spontaneous Ventilation during Anesthetic Emergence—Effect on Postoperative Atelectasis: A Randomized Controlled Trial

Heejoon Jeong, M.D., Pisitpitayasaree Tanatporn, M.D., Hyun Joo Ahn, M.D., Ph.D., Mikyung Yang, M.D., Ph.D., Jie Ae Kim, M.D., Ph.D., Hyean Yeo, M.D., Woojin Kim, M.D.

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BACKGROUND

- Despite previous reports suggesting that pressure support ventilation facilitates weaning from mechanical ventilation in the intensive care unit
- Few studies have assessed its effects on recovery from anesthesia
- Pressure support ventilation modalities are now standard on newer anesthesia machines

BACKGROUND

- Recruitment maneuver and the application of positive end-expiratory pressure (PEEP) improved intraoperative oxygenation
- The effect dissipated promptly after extubation

Whalen FX, Gajic O, Thompson GB, Kendrick ML, Que FL, Williams BA, Joyner MJ, Hubmayr RD, Warner DO, Sprung J: The effects of the alveolar recruitment maneuver and positive end-expiratory pressure on arterial oxygenation during laparoscopic bariatric surgery. Anesth Analg 2006; 102:298–305

BACKGROUND

- The emergence period contributes to approximately 39% of the total amount of postoperative atelectasis
- Postoperative atelectasis is one of the most common pulmonary complications noted
  - increases the risk of hypoxemia
  - forms the pathophysiologic basis for other postoperative pulmonary complications

Östberg E, Thorisson A, Enlund M, Zetterström H, Hedenstierna G, Edmark L: Positive end-expiratory pressure and postoperative atelectasis: A randomized controlled trial. Anesthesiology 2019; 131:809–17

BACKGROUND

- We allow patients to breathe spontaneously and assist their respiration intermittently during the transition from controlled ventilation to spontaneous respiration
- Patients who are spontaneously breathing subsequently developing atelectasis
  - remain under the influence of residual anesthetic agents and neuromuscular blockers
  - pain-induced respiratory restriction or respiratory muscle fatigue

BACKGROUND

- Pressure support ventilation applies a fixed amount of pressure throughout each breath to augment their own respiration and is one of the most comfortable ventilation modes for patients
- Pressure support ventilation during recovery from anesthesia may reduce postoperative atelectasis compared to spontaneous respiration with intermittent manual assistance
- To date, few studies have assessed the effect of pressure support ventilation on postoperative atelectasis

BACKGROUND

- Laparoscopic procedures are associated with a higher risk of postoperative atelectasis
  - High intra-abdominal pressure
  - Trendelenburg position

BACKGROUND

- The hypothesized of this study
  - pressure support ventilation reduces the incidence of postoperative atelectasis compared to spontaneous respiration with intermittent manual assistance in patients undergoing laparoscopic colectomy or robot-assisted laparoscopic prostatectomy

METHODS

- Study Design
  - single-center, randomized, controlled, patient and evaluator-blinded trial with a two-arm parallel design
  - Registered before enrollment at Samsung Medical Center Institutional Review Board and Korean Clinical Research Information Service
  - Informed consent from all participants

METHODS

- Inclusion criteria
  - Elective laparoscopic colectomy or robot assisted laparoscopic prostatectomy
  - 20 year of age or older
  - ASA Physical Status I to III

METHODS

- Exclusion criteria
  - BMI ≥ 30 kg/m^2
  - Pregnancy
  - Underlying lung disease
  - Moderate or severe obstruction observed on PFT
  - Previous lung surgery
  - Pneumothorax
  - Pulmonary tuberculosis
  - Pleural effusion
  - Expectation of difficult intubation
  - Patient's refusal

METHODS

- The dropout criteria
  - The withdrawal of consent
  - Change of surgical plan to open surgery
  - Intraoperative blood loss greater than 400ml
  - Unstable hemodynamics

METHODS

- Randomization
  - Randomized 1:1 in parallel groups by block randomization
  - Allocation was sequentially numbered and sealed in opaque envelopes
  - The attending anesthesiologists opened the envelopes 10 min before commencing the emergence procedure

METHODS

- Blinding Method
  - The patients, surgeons, sonographers, and staff of the postanesthesia care unit (PACU) were blinded
  - Attending anesthesiologists were not blinded

METHODS

- Anesthesia and Monitoring
  - CXR was performed 1 day before operation
  - No patient received sedating premedication
  - The induction and maintenance of anesthesia were standardized and identical for all patients
    - IV propofol (2.0 to 2.5 mg/kg)
    - IV rocuronium (1.0 mg/kg) then continuous rate 0.3 - 0.8 mg/kg/hr
    - maintenance 1.0 - 2.0 MAC of sevoflurane
    - IV remifentanil 0.05 to 0.2 μg/kg/ min

METHODS

- Anesthesia and Monitoring
  - Preoxygenation 2min (O_2 4 l/min)
  - Loss of spontaneous breathing , bag mask–ventilated with a Fio_2 0.8
  - Endotracheal intubation was performed 4min after the start of preoxygenation
  - Arterial catheter was placed in the radial artery for blood gas sampling and invasive blood pressure monitoring

METHODS

- Anesthesia and Monitoring
  - Mechanical ventilation : volume-controlled mode
    - FiO_2 0.4
    - Tidal volume 8 ml/kg
    - Inspiratory to expiratory ratio 1:2
    - PEEP 5 cm H_2O
    - RR 12 bpm (adjusted to maintain $ETCO_2$ 33 -45 mmHg)
    - The recruitment maneuver was not used

METHODS

- Anesthesia and Monitoring
  - Position : lithotomy with Trendelenburg
  - Intra-abdominal pressure was maintained 12-15 mmHg during abdominal insufflation
  - BP was maintained within 20% of the baseline values (Phenylephrine,ephedrine,nicardipine)
  - HR < 40 bpm , IV atropine 0.5 mg

METHODS

- Anesthesia and Monitoring
  - Maintenance fluid : Lactated Ringer's solution rate of 4 -6 ml/kg/hr
  - Crystalloid solution was administered to replace blood loss
  - IV hydromorphone 0.01 mg/kg and paracetamol 1 g
  - IV patient-controlled analgesia was applied to all patients (fentanyl)
  - In the PACU PS > 4 received rescue opioids
    (IV hydromorphone 0.01mg/kg) until the numeric rating scale < 4

METHODS

- Study Protocol
  - At the end of surgery
    - Sevoflurane was ceased
    - Anesthesiologist began the recovery protocol
    - Both groups received fresh gas flow at 4 l/min and FiO_2 of 0.4 during emergence from anesthesia

METHODS

- Study Protocol
  - Pressure support group :
    - Driving pressure 5 cm H_2O
    - PEEP 5 cm H_2O
    - Flow trigger : 2 l/min , end of breath : 30% of peak flow
    - Safety backup ventilation VT 8ml/kg , PEEP 5 cm H_2O , RR 12 bpm
    - Target VT 7-8 ml/kg , RR 10-16 bpm
    - Ventilatory support was stopped when the patient showed adequate VT > 6ml/kg , RR >10 bpm without ventilatory support
    - PEEP 5 cm H_2O was maintained until extubation

METHODS

- Study Protocol
  - Control group :
    - the emergence process was led by the discretion of the attending anesthesiologist
    - The basic strategy was to allow the patient to breathe spontaneously and only help respiration if necessary, with intermittent manual assistance

METHODS

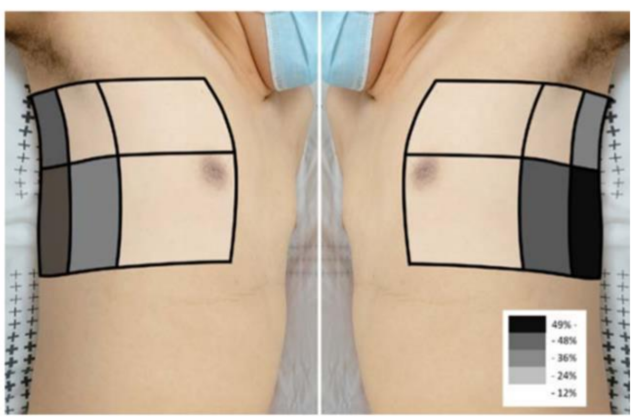
- Study Protocol
  - Train-of-four of peripheral nerve stimulator was monitored
  - TOF ≥ 3 : pyridostigmine 0.2mg/kg + glycopyrrolate 0.008 mg/kg IV
  - TOF ≤ 2 : sugammadex 2-4 mg/kg IV

METHODS

- Study Protocol
  - Extubation was performed when the patient met the following criteria
    - Obeys commands such as eye-opening or hand-grip
    - VT > 250ml
    - $ETCO_2$ < 45 mmHg
    - RR 10 - 20 breaths/min
    - Train-of-four ratio ≥ 0.9
  - After extubation , all patients were transferred to the PACU without oxygen supplementation

METHODS

- Lung Ultrasonography and Scoring System
  - All patients were evaluated using lung ultrasonography 30 min after their PACU arrival
  - Lung ultrasonography : Vivid with an 11-MHz linear transducer and real time B-mode
  - Inspection of each lung was performed at 12 lung sections
  - The following signs were assessed : the lung “sliding” sign, A-lines, B-lines, lung pulse, and air bronchograms



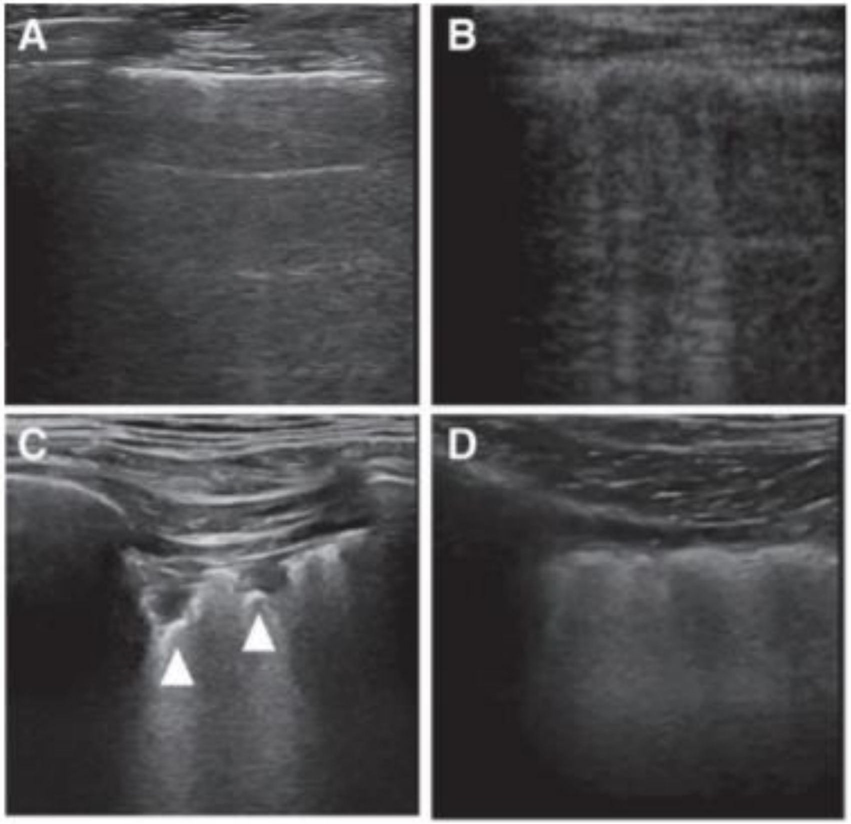


Fig. 1. Lung sonographic signs associated with atelectasis. (*A*) Score 0: normal lung. Pleura is thin and A-lines are apparent. One or two well-spaced lines per intercostal space are allowed. (*B*) Score 1: more than three well-spaced vertical lines per intercostal space (B-lines). (*C*) Score 1: juxtapleural consolidation (*arrows*) with normal pleural line. Juxtapleural consolidation is caused by a loss of lung aeration. It commonly arises from the pleural line. (*D*) Score 2: loss of A-line with multiple juxtapleural consolidations and irregular pleural lines are seen. Score 3 (loss of lung sliding and appearance of lung pulse; Supplemental Digital Content 1, http://links.lww.com/ALN/C690) and score 4 (large consolidation, no occurrence in our study) are not presented here.

METHODS

- Lung Ultrasonography and Scoring System
  - Ultrasonography was performed by two anesthesiologists
  - All measurements were conducted during deep spontaneous respiration
  - All clips were stored and interpreted by the consensus read of the two sonographers
- Arterial Blood Gases and Oxygenation
  - Arrival at the PACU without oxygen supplementation
  - SpO_2 <92% : Oxygen via nasal prong at 3 l/min

Study Outcomes and Measurements

- Primary outcome
  - The incidence of postoperative atelectasis diagnosed by lung ultrasonography at PACU
- Secondary outcome
  - PaO_2 at PACU and incidence of $SpO_2 < 92\%$ during 48h postoperatively

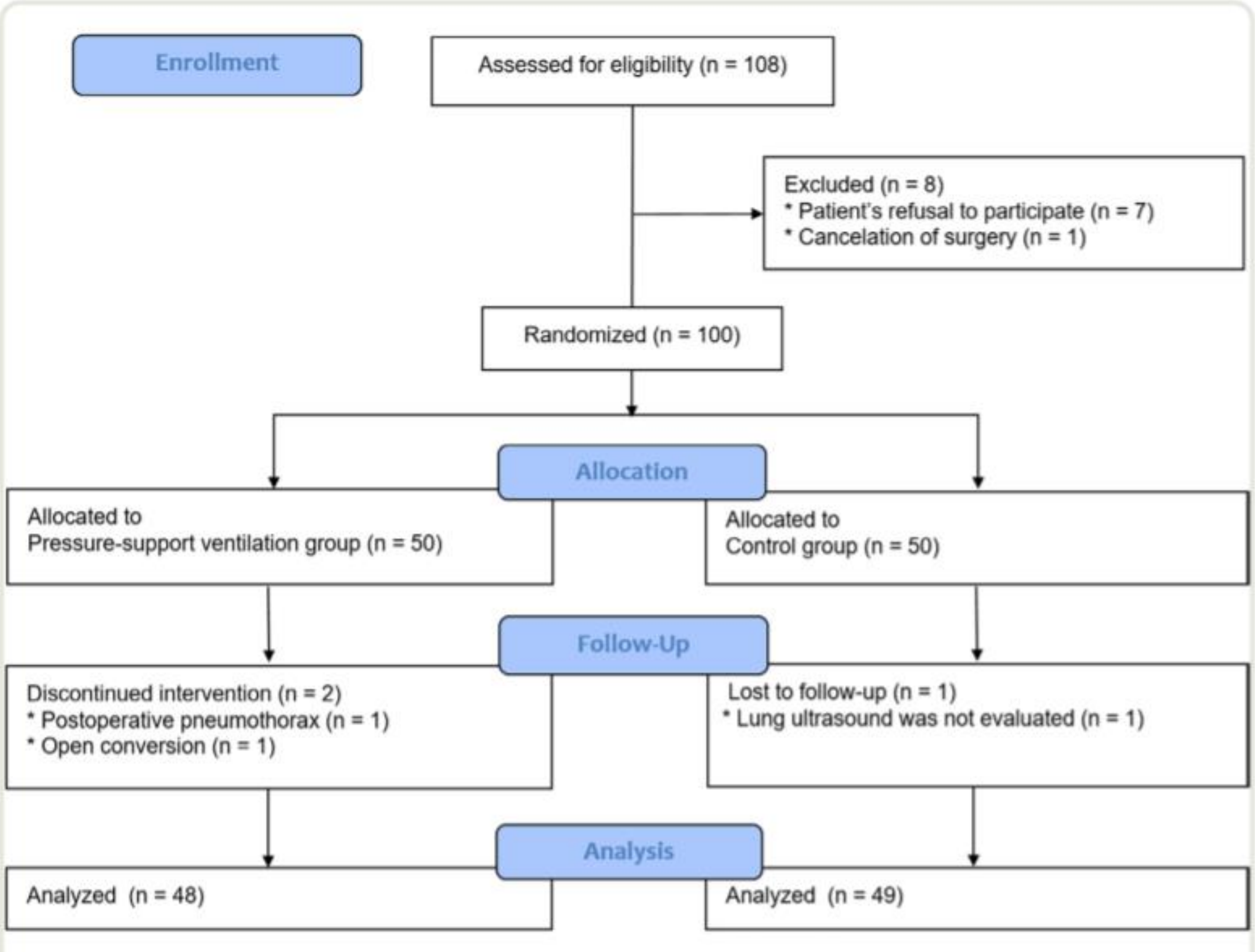
STATISTICAL ANALYSIS

- A sample size of 100 patients
- Power of 80% , P value < 0.05

STATISTICAL ANALYSIS

- MedCalc 14.12.0 were used for all analyses
- Categorical variables : counts (%)
- Continuous variables : mean ± SD or median (interquartile range)
- The normal distribution of data was evaluated using the Shapiro–Wilk test
- CIs for nonnormally distributed variables were calculated using the Hodges–Lehmann estimator
- The primary outcome : chi-square test
- The secondary outcomes : independent t test , chi-square test
- Statistical significance was defined as $P < 0.05$

RESULTS


Enrollment
Assessed for eligibility (n = 108)
Excluded (n = 8)
* Patient's refusal to participate (n = 7)
* Cancelation of surgery (n = 1)
Randomized (n = 100)
Allocation
Allocated to
Pressure-support ventilation group (n = 50)
Allocated to
Control group (n = 50)
Follow-Up
Discontinued intervention (n = 2)
* Postoperative pneumothorax (n = 1)
* Open conversion (n = 1)
Lost to follow-up (n = 1)
* Lung ultrasound was not evaluated (n = 1)
Analysis
Analyzed (n = 48)
Analyzed (n = 49)

RESULTS

Table 1. Baseline Characteristics, Operative Data, and Ventilatory Data of Participants

Variables	Control (n = 49)	Pressure Support (n = 48)
Age, yr	64 ± 9	62 ± 10
Sex, male	38 (78)	31 (65)
Body mass index, kg/m²	25 ± 3	24 ± 3
ASA Physical Status ≥ III	5 (10)	4 (8)
Smoking*	2 (4)	2 (4)
Comorbid condition		
Hypertension	23 (47)	17 (35)
Diabetes mellitus	11 (22)	10 (21)
Cardiovascular diseases†	4 (8)	3 (6)
Difficult intubation‡	6 (12)	3 (6)
Duration of surgery, min	157 ± 40	172 ± 54
Type of surgery		
Laparoscopic colectomy	22 (45)	29 (60)
Robot-assisted laparoscopic prostatectomy	27 (55)	19 (40)
Intraoperative fluid infusion, ml/min	4.5 ± 1.2	4.9 ± 2.1
Estimated blood loss, ml	118 ± 92	134 ± 111
Mean arterial pressure, mmHg	85 ± 8	88 ± 12
Heart rate, beats/min	66 ± 11	67 ± 10
Peak airway pressure,§ cm H_2O	25 [23–27]	24 [22–26]
Plateau airway pressure,§ cm H_2O	20 [18–22]	19 [17–21]
Driving pressure,§ cm H_2O	15 [13–17]	14 [12–16]
Tidal volume per predicted body weight,§ ml/kg	6 [6–7]	7 [6–8]
Respiratory rate,§ breaths/min	13 [12–14]	13 [12–14]
Static compliance,§ ml/cm H_2O	29 [25–34]	35 [31–42]
End-tidal carbon dioxide pressure,§ mmHg	36 ± 2	37 ± 2
Intraoperative Pao_2,§ mmHg	255 ± 113	222 ± 98
Use of sugammadex before extubation	22 (45)	16 (33)
Event of Spo_2 < 92% during operation	3 (6)	2 (4)
Duration of emergence, min	8 ± 3	9 ± 4
Opioid consumption during the PACU stay, fentanyl equivalent, µg	20 [0–35]	20 [0–30]

RESULTS

Table 2. Postoperative Atelectasis Outcomes in the Postanesthesia Care Unit

Variables	Control (n = 49)	Pressure Support (n = 48)	Effect Estimate (95% CI)	*P* Value
Atelectasis diagnosed by lung ultrasonography	28 (57)	16 (33)	0.58 (0.35 to 0.91)*	0.024
Atelectasis score	5 [2 to 8]	3 [1 to 6]	0.35 (–0.06 to 0.72)†	0.093
Major findings of atelectasis				
B-lines ≥ 3	25 (51)	26 (54)	1.06 (0.72 to 1.57)*	0.756
Juxtapleural consolidation with normal pleural line	12 (25)	7 (15)	0.60 (0.24 to 1.35)*	0.228
Loss of A-line with multiple juxtapleural consolidations and irregular pleural lines	35 (71)	29 (60)	0.85 (0.62 to 1.13)*	0.257
Loss of lung sliding and appearance of lung pulse	0 (0)	2 (4)	Not reported‡	0.149
Tissue-like change with or without airbronchogram	0	0		

Data are presented as n (%) or median [interquartile range].

*Effect estimate is risk ratio (two-sided 95% CI) by Wald likelihood ratio approximation test and chi-square hypothesis tests. †Effect estimate is calculated by Cohen's *d* with pooled SD. ‡Not reported because there were no patients in the control group.

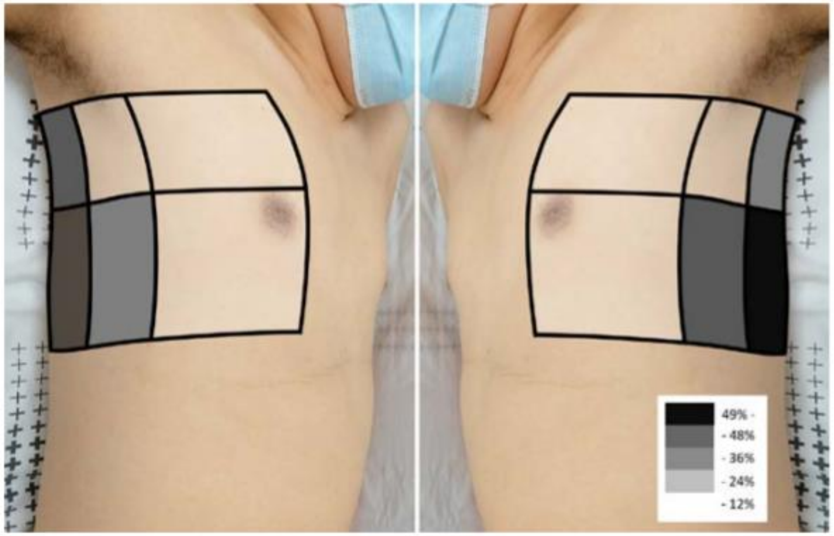


Fig. 3. The regional distribution of atelectasis. *Darker colors* indicate higher incidence. Most atelectasis occurred in the dependent area. The left lower lobe showed the highest incidence.

RESULTS

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Tissue-like change with or without airbronchogram	0	0		

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RESULTS

- SpO_2 at extubation was 100 (100 to 100) vs. 100 (100 to 100) in the control and pressure support groups, P = 0.715)

- The duration of PACU stay was 65 (56-79) min vs. 68 (60-75) min in the control and pressure support groups, P = 0.318)

RESULTS

Table 3. Secondary and Other Outcomes of Participants

Variables	Control (n = 49)	Pressure Support (n = 48)	*P* Value
Pao_2 measured in the PACU, mmHg	83 ± 13	92 ± 26	0.034
Events of Spo_2 < 92% during the PACU stay	13 (26)	11(23)	0.680
After discharge to ward			
Events of Spo_2 < 92% 48 h postoperatively	11 (22)	9 (19)	0.653
Patients who needed supplemental oxygen 48 h postoperatively	11 (22)	9 (19)	0.653
Patients who needed mechanical ventilation support	0	0	
Fever (≥ 37.5°C) 48 h postoperatively	6 (12)	9 (19)	0.376
Postoperative hospital stay, day	7 [6–8]	7 [6–8]	0.515

Data are presented as mean ± SD, n (%), or median [interquartile range].

PACU, postanesthesia care unit; Spo_2, oxygen saturation measured by pulse oximetry.

RESULTS

Table 4. *Post Hoc* Sensitivity Analysis Using Multiple Logistic Regression

Variable	Odds Ratio	95% CI	*P* Value
Sensitivity analysis using multiple logistic regression model			
Pressure support ventilation	0.381	0.159–0.91	0.030
Age, per yr	1.03	0.98–1.08	0.232
Body mass index ≥ 25 kg/m^2	0.70	0.274–1.79	0.459
Cardiovascular diseases*	2.16	0.171–27.4	0.552
ASA Physical Status ≥ III	1.28	0.132–12.3	0.833
Duration of surgery, per min	1.00	0.99–1.00	0.504

Multiple logistic regression with a simultaneous entering of variables associated with postoperative atelectasis was conducted for *post hoc* sensitivity analysis.

*Cardiovascular diseases included angina pectoris and myocardial infarction.

ASA, American Society of Anesthesiologists.

RESULTS

- Primary outcome
  - The incidence of postoperative atelectasis diagnosed by lung ultrasonography
    - 28 of 49 (57%) in the control group
    - 16 of 48 (33%) in the pressure support groups
    - P = 0.024

DISCUSSION

- Due to the lack of reports in surgical patients, anesthesiologists may be concerned
  - develop respiratory failure immediately after extubation
  - need to watch our patients' spontaneous breathing to predict the patients' physiologic conditions after extubation
- There is no evidence that a short duration of pressure support ventilation would have a significant impact on respiratory muscle dysfunction

DISCUSSION

- Pellegrini et al. demonstrated that high continuous positive airway pressure reduced respiratory drive and the contractile activity of the diaphragm in patients in the ICU

- In study, pressure support ventilation was not associated with postextubation hypoxia or extubation failure
- pressure support ventilation contributed to the lower incidence of postoperative atelectasis and higher oxygenation

Pellegrini M, Hedenstierna G, Roneus A, Segelsjö M, Larsson A, Perchiazzi G: The diaphragm acts as a brake during expiration to prevent lung collapse. Am J Respir Crit Care Med 2017; 195:1608–16

DISCUSSION

- The possible mechanisms for how pressure support ventilation shows a lower incidence of postoperative atelectasis
  - Driving pressure helps lung expansion during inspiration with reduced work of breathing by as much as 30-40%
  - PEEP increases the end-expiratory lung volume and counteracts airway closure with a dominant effect in the dependent lung region

DISCUSSION

- The use of low FiO_2 has been the most commonly suggested technique to decrease atelectasis during recovery from anesthesia
- An FiO_2 of 0.3-0.4 before extubation resulted in reduced incidence of postoperative atelectasis compared to an FiO_2 of 1.0

DISCUSSION

- In the current study, the incidence of postoperative atelectasis was as high as 57%,even though low Fio2(0.4)
- Pressure support ventilation reduced the incidence of atelectasis by 42%

- Pressure support ventilation is another armamentarium against postoperative atelectasis

DISCUSSION

- Most of the previous studies which compared ventilatory techniques used CT to diagnose immediate postoperative atelectasis
- Lung ultrasonography is a fast, simple, noninvasive, and radiation-free technique
  - sensitivity 88%
  - specificity 92%
  - diagnostic accuracy 91%
- The atelectasis scoring system using ultrasonography has not yet been standardized

Yu X, Zhai Z, Zhao Y, Zhu Z, Tong J, Yan J, Ouyang W: Performance of lung ultrasound in detecting peri-operative atelectasis after general anesthesia. Ultrasound Med Biol 2016; 42:2775–84

LIMITATION

- Lung ultrasonography depends on the sonographer's skill, and requires patient cooperation
- The median lung ultrasound score (5 and 3) and the incidence of hypoxia (22% and 19%) during 48hr postoperatively were not different between the two groups
  - atelectasis is lowgrade
  - antiatelectasis effect of pressure support ventilation is transient
- Atelectasis was diagnosed by consensus reading of two sonographers (inter- or intrarater variability exists)

LIMITATION

- Low FiO_2 (0.4) was maintained during emergence, and patients did not receive oxygen at PACU to avoid absorption atelectasis in both groups
- Nine patients with unexpected difficult intubation
  - Using low FiO_2 can be risky in patients with the previous difficult intubation
- The effect of pressure support ventilation is not known in patients with COPD, obesity, or other significant comorbidities

CONCLUSION

- Pressure support ventilation during emergence from general anesthesia showed a lower incidence of postoperative atelectasis compared to the patient's spontaneous respiration with intermittent manual assistance in laparoscopic colectomy and robot-assisted laparoscopic prostatectomy

- Because this result was derived from the low-risk patients of postoperative atelectasis, subsequent validation studies for high-risk patients such as obesity and COPD are required

Critical Appraisal : RCT

- Does this study address a clear question?

1. Were the following clearly stated:	Yes	Can't tell	No
• Patients	✓		
• Intervention	✓		
• Comparison Intervention	✓		
• Outcome(s)	✓		

Critical Appraisal : RCT

- Are the results of this single trial valid?

	Yes	Can't tell	No
2. Was the assignment of patients to treatments randomised?	✓		
3. Was the randomisation list concealed? Can you tell?	✓		
4. Were all subjects who entered the trial accounted for at it's conclusion?	✓		
5. Were they analysed in the groups to which they were randomised, i.e. intention-to-treat analysis	✓		

Critical Appraisal : RCT

- Are the results of this single trial valid?

	Yes	Can't tell	No
6. Were subjects and clinicians 'blind' to which treatment was being received, i.e. could they tell?	✓		
7. Aside from the experimental treatment, were the groups treated equally?	✓		
8. Were the groups similar at the start of the trial?	✓		

Critical Appraisal : RCT

- What were the results?

9. **How large was the treatment effect?** Consider • How were the results expressed (RRR, NNT, etc).	?
10. **How precise were the results?** Were the results presented with confidence intervals?	YES

Critical Appraisal : RCT

- Can I apply these valid, important results to my patients?

11. Do these results apply to my patient?	Yes	Can't tell	No
• Is my patient so different from those in the trial that the results don't apply?			✓
• How great would the benefit of therapy be for my particular patient?	✓		
12. Are my patient's values and preferences satisfied by the intervention offered?			
• Do I have a clear assessment of my patient's values and preferences?	✓		
• Are they met by this regimen and its potential consequences?	✓		