A nationwide survey of intraoperative management for one-lung ventilation in Taiwan: time to accountable for diversity in protective lung ventilation

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Abstract

Background: There is a major paradigm shift for intraoperative mechanical ventilator support by the introduction of lung protective ventilation strategies to reduce postoperative pulmonary complications and improve overall clinical outcomes in non-thoracic surgeries. However, there is currently a lack of standardized practice guideline for lung protection during thoracic surgeries that require one-lung ventilation (OLV). This study aimed to collect the expert opinions of the thoracic anesthesiologists in perioperative care for OLV surgery in Taiwan.

Methods: This prospective cross-sectional study was undertaken in 16 tertiary hospitals in Taiwan from January to February 2019. A structured survey form was distributed across the participating hospitals and the thoracic anesthesiologists were invited to complete the form voluntarily. The survey form consisted of three parts, including the basic information of the institutional anesthesia care standards, ventilatory settings for a proposed patient receiving OLV surgery and expert opinions on OLV.

Results: A total of 71 thoracic anesthesiologists responded to the survey. Double-lumen tubes are the most commonly used (93.8%) airway devices for OLV. The most commonly recommended ventilator setting during OLV is a tidal volume of 6-7 ml/kg PBW (67.6%) and a PEEP level of 4-6 cmH₂O (73.5%). Dual controlled ventilator modes are used by 44.1% of the anesthesiologists. During OLV, high oxygen fraction (FiO₂ >0.8) is more commonly supplemented to achieve an oxygen saturation higher than 94%. The consensus of anesthesiologists on the indices for lung protection in thoracic surgery is considerably low. Large majority of the anesthesiologists (91.5%) highly recommend that an international clinical practice guideline on the protective lung ventilation strategy for thoracic anesthesia should be established.

Conclusions: This study found that the thoracic anesthesiologists in Taiwan share certain common practices in ventilator support during OLV. However, they are concerned about the lack of fundamental clinical evidences to support the beneficial outcomes of the current lung protective strategies applicable to OLV. Large-scale trials are needed to form an evidence-based clinical practice guideline for thoracic anesthesia.

Background

One-lung ventilation (OLV) is the most commonly used technique for selective lung isolation during thoracic procedures. Intraoperative lung isolation can be managed by means of double-lumen endotracheal tube (DLT), bronchial blocker (BB), or nonintubated method [1, 2]. In addition to reduction of lung volume, OLV is also impeded by significant decline in lung compliance at lateral decubital position, formation of intrapulmonary shunting and exposure of the dependent lungs to ventilator-induced lung injury (VILI) [3]. The independent lung is injured by surgical manipulation and atelectrauma. Re-expansion of the collapsed independent lung at the end of surgical procedure inevitably results in ischemia-reperfusion injury and induction of systemic inflammatory response, which in turn leads to biotrauma [3,

4]. Therefore, a significantly high pulmonary complication of up to 14–28.4% was reported in patients received OLV surgery [5].

In the recent two decades, there is a major paradigm shift for mechanical ventilator support during operation by the introduction of intraoperative lung protective ventilation (IOLPV) strategies. Some of these changes include a low tidal volume (V_t), moderate levels of positive end-expiratory pressure (PEEP), optimal driving pressure (ΔP) and the appropriate use of lung recruitment maneuver [6]. IOLPV strategies have been shown to reduce post-operative pulmonary complications and improve overall clinical outcomes in intermediate and high-risk patients undergoing major abdominal surgery [6–8]. However, very limited clinical evidence is currently available to support the application of appropriate protective lung ventilation during OLV. The optimal levels of intraoperative use of oxygen fraction, the ventilatory settings for volume and pressure variables during OLV and re-expansion phases for lung recruitment are debating. Furthermore, diversities in clinical practice on airway management, advanced monitoring systems and pain control strategies for thoracic surgery are also observed.

Since the international clinical practice guidelines for intraoperative OLV are yet to be established, we conducted a nationwide survey among the thoracic anesthesiologists in Taiwan to determine the current status in practicing ventilatory support and anesthesia care during OLV surgery, and analyze the levels of agreement in the intraoperative ventilatory settings among the experts in thoracic anesthesia.

Methods

The study was approved by the ethics committee and the institutional review board of E-Da hospital, Kaohsiung, Taiwan (Approval number EMRP–107–114). We administered a physician-based, cross-sectional survey among 16 university hospitals or tertiary medical centers in Taiwan from 1 January 2019 to 28 February 2019. A structured survey form was distributed to the participated hospitals, and the thoracic anesthesiologists were invited to complete the survey voluntarily. The survey form consisted of three parts, including the basic information of the institutional anesthesia care standards, ventilatory settings for a proposed patient receiving OLV surgery and expert opinions on OLV (supplementary form 1). A thoracic anesthesiologist is defined as a registered anesthesiologist who commits to thoracic anesthesia service for at least two working days in a week. All findings are presented as descriptive data without comparative statistical analysis.

Results

A total of 71 thoracic anesthesiologists from the 16 participated hospitals across the four cardinal regions of Taiwan responded to the survey, but only 68 participants completed the second part of survey form. Table 1 shows the general information of the anesthesia care standard for thoracic surgery in each institute. Eight of these hospitals (50%) undertake more than 1000 thoracic surgeries each year (Table 1). Double-lumen endotracheal tube is the first-choice airway device (93.8%) for intraoperative lung isolation, and most of the institutes employ intravenous patient-controlled analgesia (IVPCA) as the first-line pain

control method after thoracic surgery (Table 1). Arterial catheterization is the standard intraoperative invasive hemodynamic monitoring system recommended for thoracic surgery, and 87.5% of institutes routinely apply bispectral index (BIS) for the monitoring of anesthetic depth (Table 1).

Part II of the form surveyed the intraoperative ventilatory settings managed by the thoracic anesthesiologists regarding a female patient with a predicted body weight (PBW) of 51kg who was proposed to receive OLV for right middle and lower lung lobectomy (Supplementary form 1). 44.1% (30/68) of the anesthesiologists applied the dual controlled ventilator modes (i.e. pressure control with volume guaranteed (PCV-VG) or pressure regulated volume control (PRVC) mode) for OLV support; while 30.9% (21/68) and 22.1% (15/68) of the responders used the conventional volume-controlled and pressure-controlled modes, respectively (Table 2). High inspiratory fractions of oxygen ($\text{FiO}_2 > 80\%$) were more commonly administered during OLV (64.7%) (Table 2). Most of the anesthesiologists ventilated the patient with a Vt of 6–8 ml/kg/PBW (91.1%, 62/68) and a PEEP of 2–6 cmH₂O (86.8%, 59/68) (Table 2). A peak inspiratory pressure (PIP) less than 30 cmH₂O was considered the clinically acceptable threshold to avoid barotrauma in the dependent lung during OLV (Table 2). Only few anesthesiologists permitted levels of expiratory CO₂ (EtCO₂) greater than 50mmHg (10.3%, 7/68) and levels of peripheral oxygen saturation (SpO₂) lower than 94% (42.6%, 29/68) during operation (Table 2). 42.6% (29/68) of the responders would consider reducing FiO₂ when a SpO₂ $\geq$ 98% was measured (Table 2). At the end of OLV, hand squeezing method was the most commonly used maneuver to recruit the independent lung (82.4%, 56/68).

Part III of the survey form collected the expert opinions of the thoracic anesthesiologists in the protective lung ventilation strategy during OLV. Optimal levels of Vt and PIP are suggested as the two most important ventilatory parameters for lung protection during OLV (Fig. 1). However, the agreements of anesthesiologists on these two indexes are still considerably low (40.0% and 33.8%, respectively). The proportions of these experts who consider other parameters (i.e. PEEP, FiO₂, ΔP , ventilator mode and recruitment maneuver) as the most important indexes for lung protection during thoracic surgery are extremely low (<5%). Most importantly, 91.5% (65/71) of the thoracic anesthesiologists highly recommend that an international clinical practice guideline on the protective lung ventilation strategy for thoracic anesthesia should be established.

Discussion

This survey indicates that most centers in Taiwan employ DLT for separated lung ventilation. Arterial catheter and BIS are the commonly used perioperative monitoring systems, and 50% of these centers consider IVPCA for postoperative pain control. During OLV, most thoracic anesthesiologists recommended high oxygen fraction supplement ($\text{FiO}_2 > 80\%$) and ventilated the patients with a tidal volume of 6–8 ml/kg/PBW and a PEEP of 2–6 cmH₂O using the dual-controlled mode. A PIP less than 30 cmH₂O is considered the threshold to avoid barotrauma. Most thoracic anesthesiologists try to maintain relatively normal levels of CO₂ and SpO₂ during OLV. Manual hand squeezing method is more often used

for lung recruitment at the end of operation. The Taiwanese thoracic anesthesiologists urge for an international practice guideline for protective lung ventilation during OLV.

One similar nationwide survey was reported by the Italian group in 2013. Consistent with our survey, 96% of the Italian centers used a DLT as the first choice for intraoperative lung separation [1]. A total of 39% of the Italian centers recommended epidural analgesia for postoperative pain management. Similar to our analysis, very few centers conducted paravertebral or intercostal block for pain control. According to the American Pain Society clinical practice guidelines, thoracic epidural analgesia is the gold standard for management of surgical pain after thoracotomy [9]. However, less invasive loco-regional techniques, such as paravertebral block, intercostal block and serratus anterior plane block are the more favorable approaches than epidural analgesia for the mini-invasive thoracoscopic surgery due to less side effects and improved safety profile [10]. Since majority of the thoracic surgeries are underwent using video-assisted thoracoscopy in Taiwan [11], the fact that fewer centers listed epidural analgesia as the first-line analgesia method is therefore reasonable. Nevertheless, the applications of other loco-regional blocks for pain control after thoracic surgery should be encouraged.

The main objective of this survey was to determine the strategies of ventilatory support during and after OLV. Compared with the Italian study reported 6 years ago, more Taiwanese thoracic anesthesiologists ventilated the patients using the dual-controlled ventilatory modes (PRVC or PCV-VG mode) during OLV. These dual-controlled modes deliver the preset tidal volumes with lowest optimal airway pressure, which may theoretically reduce the risk of barotrauma [12]. Although there were several clinical studies suggested that dual-controlled modes enhanced oxygenation parameters with improved respiratory mechanics during separated lung ventilation [13–15], large-scale clinical trials are needed to confirm the overall pulmonary protective outcomes of these modern ventilator modes in the dependent lung during thoracic surgery.

Low tidal volume (6–8 ml/kg PBW) is one of the hallmark parameters for IOLPV during non-thoracic surgery. However, the application of an “optimally low” tidal volume during OLV is not standardized. Our survey and other retrospective database analysis suggest that there are a considerably large proportion of patients continue to receive relatively high tidal volume (>7 ml/kg PBW) during OLV, which was associated with increased respiratory complications and major postoperative morbidity [16]. On the other hand, the Italian and Japanese anesthesiologists tend to recommend a low tidal volume (4 to 6 ml/kg PBW) for OLV [1, 17]. Nevertheless, opinions from the expert anesthesiologists highlight that protective ventilation in thoracic anesthesia is not simply synonymous of a low tidal volume, but also involves the appropriate application of PEEP, alveolar recruitment and other ventilatory settings during OLV [18, 19]. Most recently, a double-blind, randomized controlled trial conducted at the Samsung Medical Center (Seoul, Korea) demonstrated that driving pressure-guided ventilation (median ΔP of 9 cmH₂O) during OLV significantly reduced the incidence of postoperative pulmonary complications compared with the conventional protective ventilation (tidal volume 6 ml/kg PBW, PEEP 5 cmH₂O and recruitment) in thoracic surgery [20]. PEEP is another important element in practicing IOLPV. This survey found that most of the thoracic anesthesiologists in Taiwan apply a PEEP level of 4–6 cmH₂O during

OLV, which is comparable with mean levels (4.2 ± 1.6 cmH₂O) reported in a large retrospective analysis of the US database [16]. The authors concluded that low tidal volume failed to reduce postoperative pulmonary complications without application of adequate PEEP [16]. A previous study also indicated that individualized PEEP determined by a PEEP decrement trial significantly increased oxygenation and lung mechanics than the standardized PEEP (5 cmH₂O) [21]. However, the appropriate PEEP levels for OLV are yet to be determined by the ongoing clinical trials (Table 3).

Collapse of nondependent lung and atelectasis of dependent lung during OLV increases intrapulmonary shunt and leads to the development of intraoperative hypoxemia [22]. Therefore, higher oxygen fractions are more commonly supplemented during lung isolation procedures than the non-thoracic surgeries [17, 23]. However, oxygen therapy in clinical anesthesia is considered as a two-edged sword and excessive oxygen supplement should be avoided to prevent the potential oxygen toxicity [24]. An observational study found that higher FiO₂ during OLV was associated with significantly higher incidence of postoperative pulmonary complications (OR 1.30; 95% CI 1.04–1.65) [17]. High quality-controlled studies are thus essential to compare the clinical outcomes of low versus high fractions of oxygen used for OLV.

The most important message addressed by the Taiwanese thoracic anesthesiologists is the lack of consensus in the IOLPV during thoracic surgery, particularly at the OLV phase. This study found that the agreement in the ventilator-derived parameters (i.e. tidal volume, PIP, PEEP and ΔP) for the guidance of lung protection during OLV is very low among the thoracic anesthesiologists (degrees of agreement: Vt > PIP > PEEP > FiO₂ > ΔP > mode > recruitment; Fig. 1). In fact, a number of prospective randomized controlled trials are currently undertaking, including several international multicenter studies, to determine the strategy for lung protective ventilation during thoracic surgery (Table 3).

Conclusions

The thoracic anesthesiologists in Taiwan share certain general consensuses in regard to the practice in the ventilatory care during thoracic anesthesia. But, the clinical evidence in supporting the beneficial outcomes of the current lung protective strategies used during OLV is apparently insufficient. There is an essential need for establishing evidence-based practice guideline regarding IOLPV for thoracic anesthesia.

Abbreviations

ΔP : Driving pressure; BB: Bronchial blocker; BIS: Bispectral index; CI: Confidence interval; DLT: Double-lumen endotracheal tube; EtCO₂: Expiratory carbon dioxide; FiO₂: Inspiratory fractions of oxygen; IOLPV: Intraoperative lung protective ventilation; IVPCA: Intravenous patient-controlled analgesia; OLV: One-lung ventilation; OR: Odds ratio; PBW: Predicted body weight; PCV-VG: Pressure control with volume guaranteed; PEEP: Positive end-expiratory pressure; PIP: Peak inspiratory pressure; PRVC: Pressure regulated volume control; SpO₂: Peripheral oxygen saturation; VILI: Ventilator-induced lung injury; Vt: Tidal volume

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee and the institutional review board of E-DA hospital, Kaohsiung, Taiwan (Approval number EMRP–107–114). The written informed consent was received from every responder involved in this study.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

CYK, YTL, CFL and MCW conceived the study and designed the survey form. CYK and YTL collected the survey form and processed the data. CYK, YTL, CFL and MCW analyzed the data and interpreted the findings. YTL and CFL obtained the research fund. CYK and YTL drafted the manuscript. CFL and MCW supervised the study and corrected the first draft of manuscript. All authors read and approved the final manuscript.

Acknowledgements

References

1. Della Rocca G, Langiano N, Baroselli A, Granzotti S, Pravisani C. Survey of thoracic anesthetic practice in Italy. *J Cardiothorac Vasc Anesth*. 2013;27:1321–9.
2. Yang JT, Hung MH, Chen JS, Cheng YJ. Anesthetic consideration for nonintubated VATS. *J Thorac Dis*. 2014;6(1):10–13.
3. Lohser J, Slinger P. Lung Injury After One-Lung Ventilation: A Review of the Pathophysiologic Mechanisms Affecting the Ventilated and the Collapsed Lung. *Anesth Analg*. 2015;121:302–18.
4. Slutsky AS, Ranieri VM. Ventilator-induced lung injury. *N Engl J Med*. 2013;369:2126–36.
5. de la Gala F, Piñeiro P, Reyes A, Vara E, Olmedilla L, Cruz P, Garutti I. Postoperative pulmonary complications, pulmonary and systemic inflammatory responses after lung resection surgery with prolonged one-lung ventilation. Randomized controlled trial comparing intravenous and inhalational anaesthesia. *Br J Anaesth*. 2017;119:655–63.
6. Güldner A, Kiss T, Serpa Neto A, Hemmes SN, Canet J, Spieth PM, Rocco PR, Schultz MJ, Pelosi P, Gama de Abreu M. Intraoperative protective mechanical ventilation for prevention of postoperative pulmonary complications. *Anesthesiology*. 2015;123:692–713.
7. Severgnini P, Selmo G, Lanza C, Chiesa A, Frigerio A, Bacuzzi A, Dionigi G, Novario R, Gregoretti C, de Abreu MG, et al. Protective Mechanical Ventilation during General Anesthesia for Open Abdominal Surgery Improves Postoperative Pulmonary Function. *Anesthesiology*. 2013; 118:1307–21.
8. Futier E, Constantin JM, Paugam-Burtz C, Pascal J, Eurin M, Neuschwander A, Marret E, Beaussier M, Gutton C, Lefrant JY, et al. A trial of intraoperative low-tidal-volume ventilation in abdominal surgery. *N Engl J Med*. 2013;369:428–37.
9. Chou R, Gordon DB, de Leon-Casasola OA, Rosenberg JM, Bickler S, Brennan T, Carter T, Cassidy CL, Chittenden EH, Degenhardt E, et al. Management of postoperative pain: a clinical practice guideline from the American pain society, the American society of regional anesthesia and pain medicine, and the American society of anesthesiologists' committee on regional anesthesia, executive committee, and administrative council. *J Pain*. 2016;17:131–157.
10. Piccioni F, Segat M, Falini S, Umari M, Putina O, Cavaliere L, Ragazzi R, Massullo D, Taurchini M, Del Naja C, et al. Enhanced recovery pathways in thoracic surgery from Italian VATS Group: perioperative analgesia protocols. *J Thorac Dis*. 2018;10(Suppl 4):S555-S563.
11. Hung MH, Chen JS, Cheng YJ. Cheng. Precise anesthesia in thoracoscopic operations. *Curr Opin Anaesthesiol*. 2019;32(1):39–43.
12. Kothari A, Baskaran D. Pressure-controlled volume guaranteed mode improves respiratory dynamics during laparoscopic cholecystectomy: A comparison with conventional modes. *Anesth Essays Res*. 2018;12:206–12.

13. Pu J, Liu Z, Yang L, Wang Y, Jiang J. Applications of pressure control ventilation volume guaranteed during one-lung ventilation in thoracic surgery. *Int J Clin Exp Med*. 2014;7(4):1094–1098.
14. Song SY, Jung JY, Cho MS, Kim JH, Ryu TH, Kim BI. Volume-controlled versus pressure-controlled ventilation-volume guaranteed mode during one-lung ventilation. *Korean J Anesthesiol*. 2014;67:258–263.
15. Mahmoud K, Ammar A, Kasemy Z. Comparison Between Pressure-Regulated Volume-Controlled and Volume-Controlled Ventilation on Oxygenation Parameters, Airway Pressures, and Immune Modulation During Thoracic Surgery. *J Cardiothorac Vasc Anesth*. 2017;31(5):1760–1766.
16. Blank RS, Colquhoun DA, Durieux ME, Kozower BD, McMurry TL, Bender SP, Naik BI. Management of one-lung ventilation: impact of tidal volume on complications after thoracic surgery. *Anesthesiology*. 2016;124:1286–95.
17. Okahara S, Shimizu K, Suzuki S, Ishii K, Morimatsu H. Associations between intraoperative ventilator settings during one-lung ventilation and postoperative pulmonary complications: a prospective observational study. *BMC Anesthesiol*. 2018;18(1):13.
18. Kozian A, Schilling T. Protective Ventilatory Approaches to One-Lung Ventilation: More than Reduction of Tidal Volume. *Curr Anesthesiol Rep*. 2014;4:150–159.
19. Meleiro H, Correia I, Charco Mora P. New evidence in one-lung ventilation. *Rev Esp Anesthesiol Reanim*. 2018;65(3):149–153.
20. Park M, Ahn HJ, Kim JA, Yang M, Heo BY, Choi JW, Kim YR, Lee SH, Jeong H, Choi SJ, et al. Driving Pressure during Thoracic Surgery: A Randomized Clinical Trial. *Anesthesiology*. 2019;130:385–93.
21. Ferrando C, Mugarra A, Gutierrez A, Carbonell JA, García M, Soro M, Tusman G, Belda FJ. Setting individualized positive end-expiratory pressure level with a positive end-expiratory pressure decrement trial after a recruitment maneuver improves oxygenation and lung mechanics during one-lung ventilation. *Anesth Analg*. 2014;118:657–65.
22. Campos JH, Feider A. Hypoxia During One-Lung Ventilation-A Review and Update. *J Cardiothorac Vasc Anesth*. 2018;32:2330–2338.
23. Suzuki S, Mihara Y, Hikasa Y, Okahara S, Ishihara T, Shintani A, Morimatsu H, Sato A, Kusume S, Hidaka H, et al. Current Ventilator and Oxygen Management during General Anesthesia: A Multicenter, Cross-sectional Observational Study. *Anesthesiology*. 2018;129:67.
24. Martin DS, Grocott MP. III. Oxygen therapy in anaesthesia: the yin and yang of O₂. *Br J Anaesth*. 2013;111:867–71.

Tables

Table 1. The basic information of the anesthesia care standard for thoracic surgery.

Cases of thoracic surgeries per year	
>1000	50.0%
≤1000	50.0%
Lung isolation techniques for OLV	
Double-lumen endotracheal tube	93.8%
Bronchial blockers	6.3%
Laryngeal mask	0
Non-intubation	0
Postoperative analgesic management for OLV	
Intravenous patient-controlled analgesia	50.0%
Intercostal block	25.0%
Epidural analgesia	18.8%
Intravenous nonsteroidal antiinflammatory drug	6.3%
Paravertebral block	0
Perioperative monitoring systems during OLV	
Arterial catheter	100%
Bispectral index	87.5%
Central venous catheter	43.8%
Non-calibrated cardiac output monitor	12.5%
Pulmonary artery catheter	0

Table 2. The intraoperative ventilatory settings managed by the thoracic anesthesiologists.

Ventilator mode	
Pressure-controlled	22.1%
Volume-controlled	30.9%
Pressure control with volume guaranteed (PCV-VG) or pressure regulated volume control (PRVC)	44.1%
Other	2.9%
FiO2	
100%	27.9%
80-99%	36.8%
60-79%	26.5%
40-59%	8.8%
<40%	0
Tidal volume	
<6 ml/kg per PBW	1.5%
6 ml/kg per PBW	32.4%
7 ml/kg per PBW	35.3%
8 ml/kg per PBW	23.5%
9 ml/kg per PBW	7.4%
>9 ml/kg per PBW	0
Positive end-expiratory pressure	
0-2 cmH2O	2.9%
2-4 cmH2O	13.2%
4-6 cmH2O	73.5%
6-8 cmH2O	8.8%
8-10 cmH2O	1.5%
>10 cmH2O	0
Peak airway pressure	
15 cmH2O	0
20 cmH2O	1.5%
25 cmH2O	4.4%
30 cmH2O	82.4%
>30 cmH2O	11.8%
End-tidal CO2	
<35 mmHg	4.4%
35-39 mmHg	29.4%
40-44 mmHg	33.8%
45-49 mmHg	22.1%
≥50 mmHg	10.3%
SpO2	
98-100%	11.8%
95-97%	45.6%
92-94%	36.8%
88-91%	4.4%
85-87%	1.5%
Decrease FiO2 if SpO2 > 98%	
No	57.4%
Yes	42.6%
Lung recruitment maneuver after OLV	
Hand squeezing method	82.4%
Stepwise tidal volume increase method	8.8%
Stepwise PEEP increase method	8.8%

Table 3. Ongoing ClinicalTrial.gov registered trials regarding OLV during thoracic surgery

Title of trial	Location of trial	Interventions and outcome measures	<i>ClinicalTrial.gov</i> registration #
Effect of Lung Protective One-lung Ventilation with Fix and Variable PEEP on Oxygenation and Outcome	Hungary, single center	<u>Interventions</u> Under tidal volume 6 mL/kg/PBW, compare fix 5 cmH ₂ O PEEP and variable PEEP with recruitment maneuvers. <u>Outcome Measures</u> Primary: intraoperative oxygenation Secondary: postoperative complications and survival	NCT03968120
Optimal Level of PEEP in Protective One-lung Ventilation	Korea, single center	<u>Interventions</u> Under tidal volume 5 mL/kg/PBW, compare 3, 6, and 9 cmH ₂ O PEEP and variable PEEP. <u>Outcome Measures</u> Primary: modified lung ultrasound score Secondary: intraoperative desaturation, PaO ₂ /FiO ₂ , plasma inflammatory cytokines, postoperative desaturation and pulmonary complication	NCT03856918
Electrical Impedance Tomography in One-Lung Ventilation	Chile, single center	<u>Interventions</u> Compare three tidal volumes (4, 6 and 8 mL/kg/PBW) and two PEEP's (6 cmH ₂ O and best PEEP obtained after a recruitment maneuver and decremental titration). <u>Outcome Measures</u> Ventilation/perfusion ratio, pulmonary mechanics, arterial gas measurement	NCT03728010
Individualized vs Low PEEP in One Lung Ventilation	US, single center	<u>Interventions</u> Compare individualized PEEP (max lung compliance) and low PEEP (5 cmH ₂ O). <u>Outcome Measures</u> Primary: cerebral oximetry Secondary: arterial and venous blood oxygen tension, venous blood oxygen saturation, cardiac output, phenylephrine dose	NCT03569774
Individualized Perioperative Open-	International, multicenter	<u>Interventions</u>	NCT03182062

Lung Ventilatory
Strategy During One-
Lung Ventilation
(iPROVE-OLV)

Under tidal volume 5-6
mL/kg/PBW, compare alveolar
recruitment maneuver plus
PEEP titration trial and lung
protective ventilation (PEEP 5
cmH₂O).
Outcome Measures
Primary: postoperative
pulmonary complications
Secondary: postoperative
complications, length of hospital
stay

Protective Ventilation
with High Versus Low
PEEP During One-
lung Ventilation for
Thoracic Surgery
(PROTHOR)

International,
multicenter

Interventions
Under tidal volume 5
mL/kg/PBW, compare higher
PEEP (PEEP 10 cmH₂O+lung
recruitment) and lower PEEP
(PEEP 5 cmH₂O only).
Outcome Measures
Primary: postoperative
pulmonary complications

NCT02963025

PaO₂/FiO₂: partial pressure of arterial oxygen/fraction of inspired oxygen ratio; PBW: predicted body weight; PEEP: positive end-expiratory pressure; OLV: one-lung ventilation

Figures

Figure 1

The most important parameters for ventilator setting during OLV recognized by the thoracic anesthesiologists. 1 indicates the most important parameter, and >5 indicates the least important parameter. The priority of these parameters is graded in accordance to the opinions and experiences of the individual anesthesiologists.

Supplementary Files

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