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RESEARCH

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Effects of the disconnection technique and preemptive one-lung ventilation on lung collapse during one-lung ventilation in thoracoscopic surgery

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Abstract

Background During thoracoscopic surgery with one-lung ventilation (OLV), achieving lung collapse is critical for providing surgeons with a good visibility of the surgical field and to minimise tissue compression. The aim of this study was to evaluate the efficacy of both the disconnection technique and preemptive one-lung ventilation in facilitating lung collapse during thoracoscopic surgery using a double-lumen tube (DLT).

Methods Ninety-seven eligible patients were included and randomly divided into three groups. Control group: OLV was initiated when the surgeon started the skin incision and exposed the operative side. Disconnection group: OLV was started two minutes after the DLT was disconnected, this procedure started when the surgeon performed the skin incision. Preemptive group: OLV was initiated promptly after the patient was turned to the lateral position, and the bronchial tube port was clamped on the operative side at the lateral position for no less than 6 min until the pleura was opened. The primary outcome was the time to achieve satisfactory lung collapse, defined as the time required to reach a lung collapse score of eight points. The secondary outcomes included the lung collapse scores at different time points, Pleural opening times, OLV times, blood gas analysis results and the incidence of hypoxemia and pulmonary complications. The hypothesis formulated before data collection was that both the disconnection technique and preemptive OLV decrease the time to satisfactory lung collapse.

Results Compared to the control group, both the disconnection and the preemptive group had a shorter time to satisfactory lung collapse ($P < 0.001$), lung collapse in the preemptive group was superior to that in the disconnection group at one minute ($P = 0.045$), no significant differences were found among the three groups in terms of other outcomes.

Conclusion Both the disconnection technique and preemptive OLV decrease the time to satisfactory lung collapse. However, preemptive OLV results in superior early lung collapse and is therefore may more suitable for clinical application than the disconnection technique.

Trial registration The protocol of this study was registered at www. chictr. org. cn (29/07/2022, ChiCTR2200062199).

Keywords One-lung ventilation, Lung collapse, Disconnection ventilation, Preemptive one-lung ventilation

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Introduction

During thoracoscopic surgery, rapid and complete lung collapse can provide surgeons with a better field of vision, facilitate surgical procedures and minimise lung damage caused by lung tissue compression [1]. The collapse of the nonventilated lung (NVL) consists of two main phases [2]. The first is the rapid collapse phase, which occurs when the pleura is opened and air enters the pleural cavity. Due to its inherent elastic recoil force, the lung collapses rapidly, typically in less than a minute. The second phase is the slow collapse period. As the lung rapidly collapses, small airways begin to close, passive collapse ceases, and the residual gas in the lung is eliminated primarily by absorption and diffusion. Currently, all efforts to accelerate lung collapse target these two phases [3].

If one-lung ventilation (OLV) is initiated prior to opening the pleural cavity, there will be passive ventilation between the NVL and the air due to the combined effect of mediastinal displacement caused by the ventilated lung and the closed pleural cavity, which is not conducive to lung collapse [4]. The two methods commonly used in clinical practice to accelerate lung collapse are the disconnection technique and preemptive OLV: (1) Disconnection technique:the double-lumen tube (DLT) is disconnected from the ventilator,the residual gas in the lung is expelled through the elastic recoil force [5]. Many studies have confirmed that the implementation of the disconnection technique for 15 s to 2 min can accelerate lung collapse [6–9]. Some scholars choose to disconnect 2 min immediately after cutting the skin [6].There are also studies that propose maintaining two-lung ventilation until the pleural cavity is opened, followed by disconnection for 60 seconds [9]. (2) Preemptive OLV: 100% O_2 collapses the lung collapses within 6 minutes [3], recent research has demonstrated that immediate clamping of the bronchial tube port on the surgical side in the lateral position for no less than 6 min until the pleura is opened can significantly reduce the lung collapse time during OLV in thoracoscopic surgery [10, 11]. Currently, there is limited research comparing the safety and efficacy of two methods. The aim of this study was to evaluate the safety and efficacy of both methods during thoracoscopic surgery with OLV.

Methods

Study design and patients

This prospective, randomised controlled clinical trial was approved by the Ethics Committee of Army Medical Center of PLA (approval number: Yiyanlunshen (2022) No. 188) and registered with the Chinese Clinical Trial Registry (registration number: ChiCTR2200062199). Data were collected from July 2022 to February 2023, and all enrolled patients signed an informed consent form. Patient enrolment and allocation were performed according to the study flowchart (Fig. 1).

Inclusion and exclusion criteria

The inclusion criteria for this study were as follows: (1) an American Society of Anaesthesiologists physical status (ASA) I or II; (2) aged between 18 and 65 years; (3) an FEV1 ≥ 70% of the predicted value and scheduled to undergo video-assisted thoracoscopic surgery requiring OLV. Patients were excluded from the study if they: (1) Patients with evidence of abnormal expiratory recoil (forced expiratory volume in 1 s < 70% of predicted value), chronic obstructive pulmonary disease or severe asthma, pneumothorax or thoracic closed drainage; (2) undergone thoracic surgery; (3) underwent a preoperative assessment indicating possible pleural adhesions, pulmonary bullae, etc.; (4) had a risk of lung contamination by blood or infectious secretions; (5) anticipated to have difficult airways.

Patients were randomly assigned to one of three groups using a random number table method: the control group (group C), the disconnection technique group (group D) and the preemptive OLV group (group P).

Preoperative preparations and anaesthesia protocol

Upon arrival at the operating room, venous and arterial access was established, and the invasive arterial blood pressure (Edwards TruWave PX260), heart rate, blood oxygen saturation, and other basic vital signs were obtained. After denitrogenation for 5 min, anaesthesia was induced with 0.3–0.5 μg/kg of sufentanil, 0.03–0.05 mg/kg of midazolam, 0.2–0.3 mg/kg of etomidate, and 0.15–0.2 mg/kg of cisatracurium. The patients were intubated with a nonoperative lateral double-lumen tube (DLT). Commonly used pulmonary isolation tools include double-lumen endotracheal tubes and bronchial blocker, and there is insufficient evidence to show a difference in lung collapse [12]. Both have their own advantages, disadvantages, and indications, but in general, double-lumen tracheal catheters are often preferred because they can be inserted quickly, are less prone to displacement, and allow for the suctioning of secretions from either lung [13–15]. We therefore chose the double-lumen endotracheal tube as the lung isolation tool, the DLT was selected based on the preoperative chest CT scan, sex, and height [16]. The correct position of the tube was verified using a fibreoptic bronchoscope (FOB) both after intubation and after the patient was positioned. Anaesthesia was maintained with sevoflurane, propofol and remifentanil, as indicated by a BIS between 40 and 50. Cisatracurium was administered intermittently to maintain neuromuscular blockade. Perioperative blood pressure control is maintained within

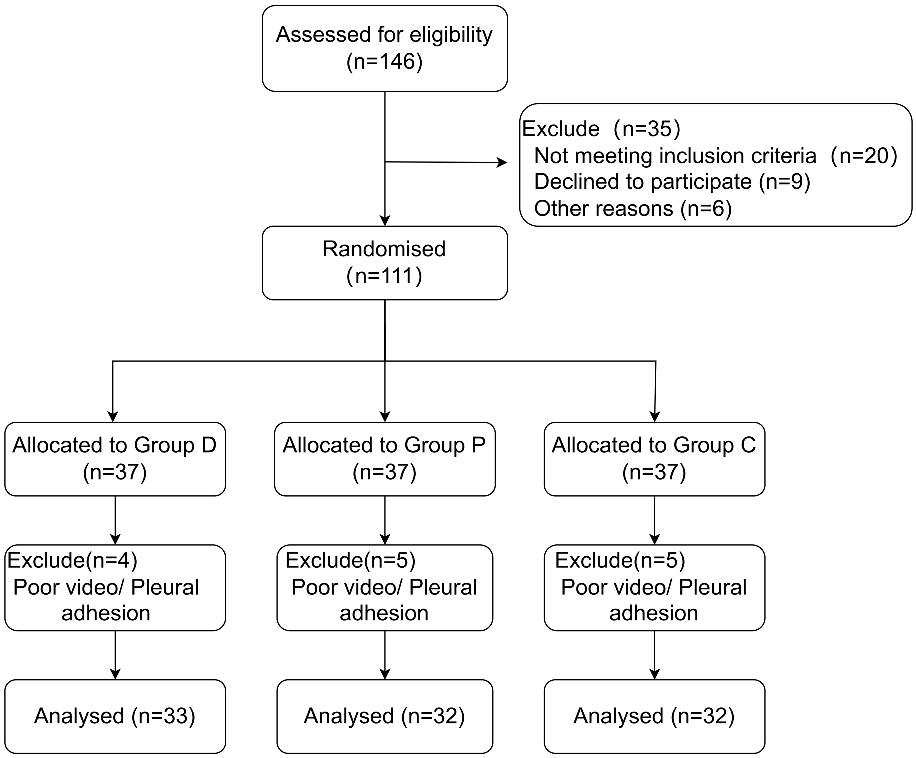


Fig. 1 Flow chart

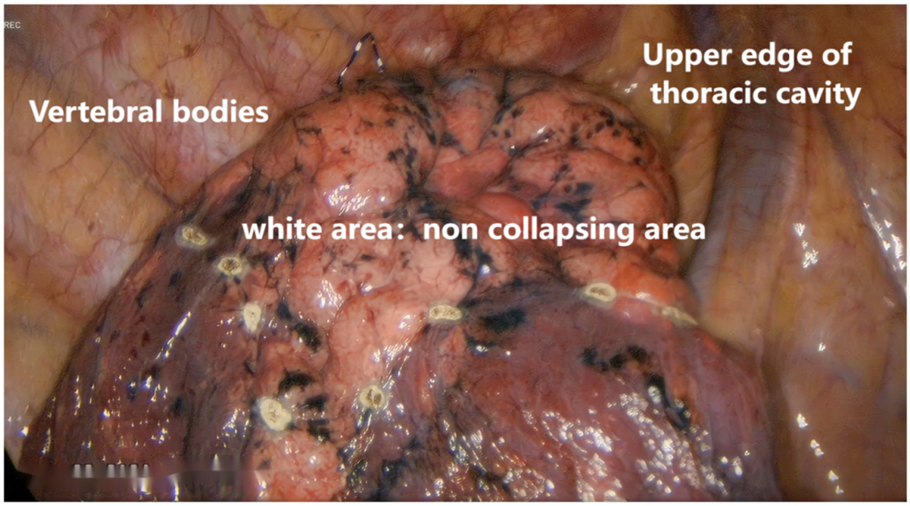
20% above or below baseline blood pressure.Two-lung ventilation (TLV) was initiated using volume-controlled ventilation: the tidal volume was 6–8 ml/kg, the respiratory rate was 12 bpm, the I/E ratio was 1:2, the positive end-expiratory pressure was 5–10 cmH2O, and the fraction of inspired oxygen was 1.0. PetCO2 was maintained at 35–45 mmHg. Different strategies for OLV were implemented based on the various groupings. In group C, OLV was initiated when the surgeon commenced the skin incision and opened the lumen of the operative side. In Group D, OLV was initiated 2 min after disconnection of the DLT. This procedure started when the surgeon performed the skin incision. If the time to open the pleura exceeded 120 s or if the pulse oxygen saturation (SpO2) decreased from the previous level, the study was stopped, and the ventilator was connected immediately. In group P, OLV was initiated promptly after the patient was turned to the lateral position while the bronchial tube port was clamped on the operative side at the lateral position until pleural opening, The time between lateral position and pleural opening was recorded, which was guaranteed to be no less than six minutes. In OLV, the tidal volume was 4–6 ml/kg, the respiratory rate was 12–15 breaths/min, the PEEP was 5–10 cmH2O, the I/E ratio was 1:2, and the fraction of inspired oxygen was 1.0. PetCO2 was maintained at 35–45 mmHg. We did not utilize negative pressure suction to facilitate lung collapse because the optimal suction pressure suction pressure, suction time are not clear, and no studies have clearly established whether it can cause occult lung injury [3, 17, 18].

Lung collapse score

Videos of the operative field were recorded during thoracoscopy after opening the pleura, and lung collapse scores were assessed by anaesthesiologist and thoracic surgeon who were blinded to the group allocation. The lung collapse scoring criteria included three main aspects [19]: space, colour, and surgeon satisfaction (Fig. 2). The lung collapse score is defined as the sum of the lung colour score, lung space score, and surgeon satisfaction score. Compared to other studies in which the satisfaction of lung collapse is solely determined at the discretion of the surgeon, our scoring criteria are more objective and accurate.

Outcomes measures

The primary outcome was the time to satisfactory lung collapse, defined as the time required to reach a lung collapse score of eight points. The secondary outcomes included lung collapse scores at different time points (1 min, 5 min, 10 min, 15 min, 20 min, 25 min, and 30 min) after pleural incision; blood gas analysis at



Scores	1	2	3	4
Space	Upper edge of thoracic cavity not visible	Upper edge of thoracic cavity Visible vertebral bodies were not	Vertebral bodies were visible	/
Colour	All white area	white area is more than half	White area is less than half	No white
Satisfaction	Dissatisfied	Basicallysatisfied	satisfied	/

Fig. 2 Lung collapse scoring criteria details

different time points (T1: preoxygenation state before the induction of anaesthesia, T2: 5 min after the start of OLV, T3: 15 min after the start of TLV, T4: 30 min after extubation); incidence rate of hypoxemia (SpO2 < 90%); basic operation-related information (Pleural opening times, OLV time) and the incidence rate of postoperative pulmonary complications (PPCs) within three days (the inclusion criteria were based on the 2015 European Perioperative Clinical Outcome standards [20]).

Statistical analysis

This study is a randomised controlled trial. Based on preliminary data, the time to satisfactory lung collapse was 14.56 ± 2.17 min in the D group, 13.92 ± 5.09 min in the P group, and 18.42 ± 3.26 min in the C group. Using PASS 15 software and one-way analysis of variance with a significance level of $\alpha = 0.05$ and $\beta = 0.10$ and assuming a 1:1:1 ratio for the three groups and a 10% dropout rate, the calculated sample size required for each group was 32 participants. The normality of continuous variables was tested using the Shapiro–Wilk normality test. The data were normally distributed, comparisons among the three groups were using one-way ANOVA, and intergroup analysis was performed using the Tukey's Honest Significant Difference test; the results are presented as the mean ± SD. The data were not normally distributed, comparisons among the three groups were using the Kruskal–Wallis test and intergroup analysis was performed using Bonferroni test, the results are presented as the median and interquartile range (IQR). Enumeration data are expressed as a percentage(%), and comparisons were made using Fisher's exact test.Statistical analyses were performed using SPSS version 27(IBM) and R Studio software version 4.3.3(R Project for Statistical Computing). All the statistical tests were two-sided, and a p value < 0.05 was considered to indicate statistical significance.

Results

A total of 97 patients were included, with 32 patients in the control group, 32 patients in the preemptive OLV group, and 33 patients in the disconnection group. Figure 1 shows a flowchart of patients enrolled in this study. The Table 1 below illustrates the baseline characteristics of the three patient groups. There were no significant differences among the three groups.

Table 1 Demographic data of study population

Variable	Group D	Group P	Group C	*p*-value
	n = 33	*n* = 32	*n* = 32	
Age,median (IQR), years	55 (42–60)	51 (47–58)	55 (50–59)	0.51
BMI,mean ± SD,kg/m^2	23.6 (2.9)	24.0 (2.5)	22.9 (2.4)	0.21
FEV1, mean ± SD,%	98.2 (8.9)	103.9 (15.8)	98.1 (12.2)	0.11
Sex — no. (%)				0.38
Male	10 (30.3%)	13 (40.6%)	15 (46.9%)	
Female	23 (69.7%)	19 (59.4%)	17 (53.1%)	
ASA — no. (%)				0.95
I	6 (18.2%)	5 (15.6%)	5 (15.6%)	
II	27 (81.8%)	27 (84.4%)	27 (84.4%)	
Surgical procedure — no. (%)				0.78
Wedge resection	7 (21.2%)	8 (25.0%)	6 (18.8%)	
Segmentectomy	12 (36.4%)	15 (46.9%)	13 (40.6%)	
Lobectomy	14 (42.4%)	9 (28.1%)	13 (40.6%)	

ASA American Society of Anesthesiologists, *FEV1* forced expiratory volume in 1 s, *BMI* Body Mass Index

There were significant differences in the time to satisfactory lung collapse among the three groups of patients. Compared with group C, groups D and P had shorter times to satisfactory lung collapse (group C:21.71 ± 3.64 min vs group D:15.72 ± 3.80 min vs group P:15.73 ± 4.83 min, $P < 0.001$). However, there was no significant difference in the time to satisfactory lung collapse between groups D and P. The incidence rate of PPCs in group C (15.6%) was higher than in group D (3%) and group P (9.4%), but it was not statistically significant ($P = 0.19$). There were no significant differences in the other indicators including pleural opening time; OLV time; incidence rate of hypoxemia among the three groups (Table 2).

The lung collapse scores at different time points are shown in Fig. 3. The lung collapse scores of groups P and D were significantly higher than those of group C at 1, 5, 10, 15, 20, and 25 min ($P < 0.05$). At one minute, the lung collapse score of group P was higher than that of group D (group P: 4[4,5] vs group D: 4[3,4], $P = 0.045$), and there were no significant differences in the lung collapse scores between the two groups at the remaining time points (Supplement Table S1).

The $PaCO_2$ and PaO_2 at different time points are shown in Fig. 4. At T2 (5 min after pleura opening), PaCO2 was significantly higher in group D than in groups C and P (group D: 40.21(4.34) mmHg vs group P: 37.34(3.96) mmHg vs group C: 37.63(2.66)mmHg, $P = 0.004$), and there were no significant differences in PaO2 or PaCO2 between the other groups (Supplement Table S2).

Discussion

Our results showed that the time to satisfactory lung collapse was shorter in the disconnection technique and preemptive OLV groups than in the conventional ventilation group. Compared with the other two groups, the preemptive OLV group exhibited a superior collapse effect during the first phase of lung collapse. The disconnection technique resulted in a significantly higher $PaCO_2$ than in the other two groups five minutes after opening the pleura, but the $PaCO_2$ subsequently returned to a level comparable to that of the other groups. None of the patients in the three groups developed hypoxemia during anaesthesia.

OLV immediately after the start of surgery often results in insufficient lung collapse, which does not meet surgical requirements. To improve the quality of and shorten

Table 2 Satisfactory lung collapse time and other outcomes

Variable	Group D (*n* = 33)	Group P (*n* = 32)	Group C (*n* = 32)	Overall p-value	D VS P p-value	D VS C p-value	P VS C p-value
Satisfactory collapse times,mean ± SD,mins	15.72(3.80)	15.73(4.83)	21.71(3.64)	< 0.001	1.00	< 0.001	< 0.001
Pleural opening times,mean ± SD,seconds	93.12(16.94)	87.22(22.16)	88.38(22.95)	0.48	0.49	0.63	0.97
OLVtime,mean ± SD,mins	81.21(23.62)	70.84(24.74)	82.75(24.83)	0.11	0.21	0.97	0.13
Pulmonary complications—no(%)	1 (3.0)	3 (9.4)	5 (15.6)	0.19	0.36	0.10	0.71
Respiratory Infection—no(%)	0 (0.0)	0 (0.0)	2 (6.3)	0.21	1.00	0.24	0.49
Atelectasis	1 (3.0)	1 (3.1)	0 (0.0)	1.00	1.00	1.00	1.00
Pleural effusion	0 (0.0)	0 (0.0)	0 (0.0)				
Respiratory failure	0 (0.0)	0 (0.0)	1 (3.1)	0.66	1.00	0.49	1.00
Pneumothorax	0 (0.0)	2 (6.3)	2 (6.3)	0.39	0.24	0.24	1.00
Hypoxemia—no(%)	0 (0.0)	0 (0.0)	0 (0.0)				

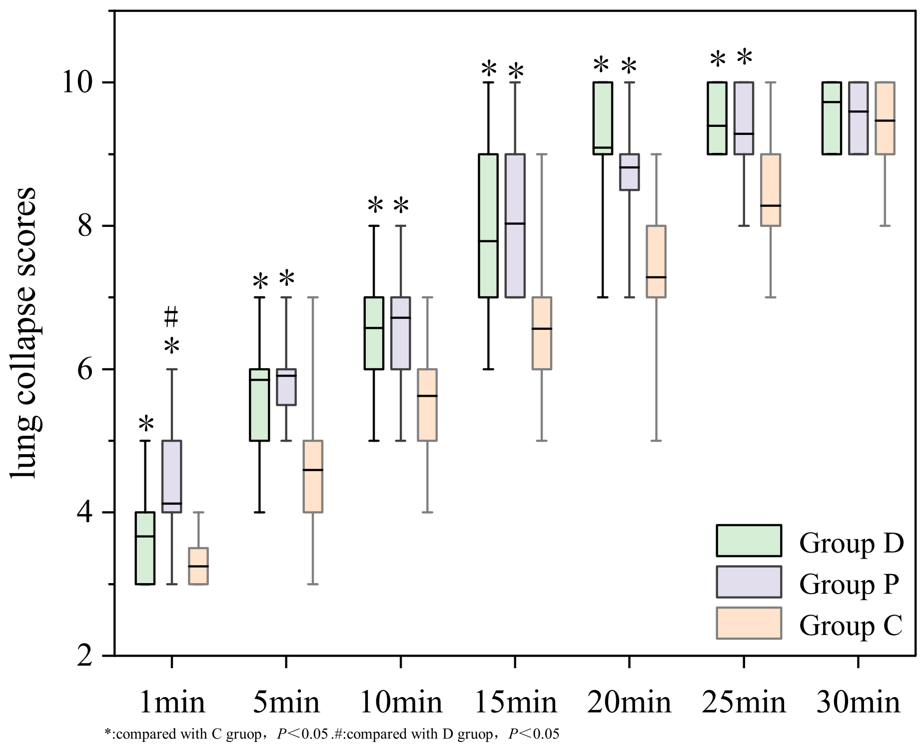


Fig. 3 Lung collapse scores at different time points

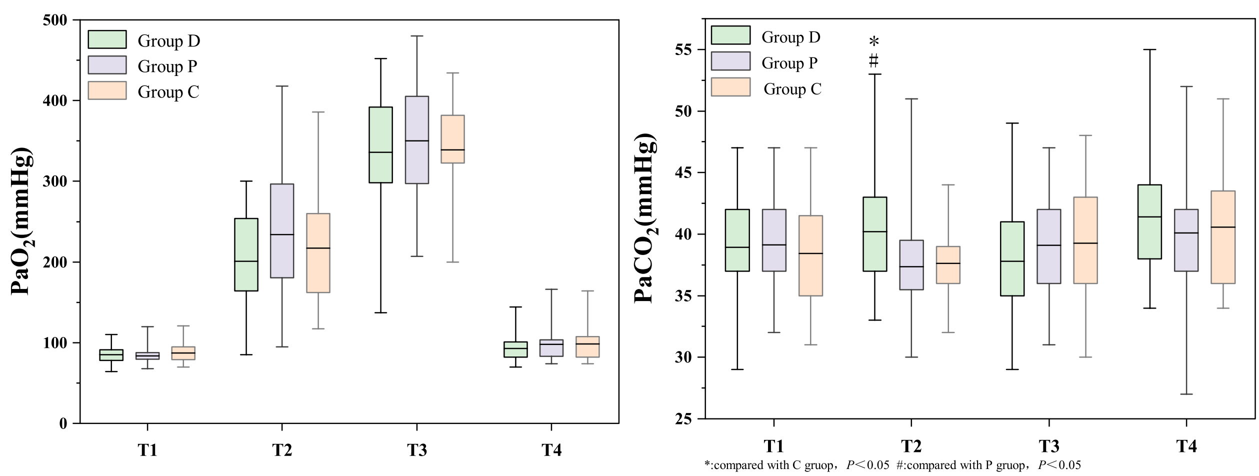


Fig. 4 Blood gas analysis results at different time points

the time to lung collapse, surgeons manually stretch and compress the lung tissue, which may lead to direct tissue injury and increase the risk of perioperative pulmonary complications [21]. To avoid passive ventilation of the nonventilated lung before opening the pleura, which can affect the quality of lung collapse, the main techniques commonly used to accelerate lung collapse are the disconnection technique and preemptive OLV, and our results show that both of these methods take less time to achieve satisfactory lung collapse and provide better lung collapse results than does conventional ventilation.

In our study, we used a two-minute disconnection technique after skin incision. Compared with the disconnection time proposed by different scholars varies from 15 s to 2 min [6–8], our protocol ensures that the pleura is already open during the disconnection period (the time to open the pleura is 93.12 ± 16.94 s) and includes the rapid occurrence of the first phase of lung collapse, preventing passive ventilation and achieving better lung collapse results. Compared with other studies proposing to open the pleura and then disconnect ventilation [9], our approach is safer (in terms of avoiding injury to the lung at the moment of opening the pleura). Previous studies have also reported a transient increase in $PaCO_2$ as a result of disconnecting ventilation [6] (it was also found that the increase in $PaCO_2$, which in turn increased cerebral blood flow and caused an increase in cerebral oxygen saturation), and despite the increase in $PaCO_2$, the transient duration and the absence of hypoxemia ensured its safety. Our study compared these two methods with the conventional OLV approach and demonstrated the superiority of these methods in achieving higher lung collapse scores at all time points. In terms of lung collapse in the first stage, the lung collapse score was higher in group P, which may be attributed to the fact that preemptive OLV avoids passive ventilation on the nonventilated side. On the other hand, the time for the nonventilated side to absorb and diffuse lung gas before the pleura is opened is longer; therefore, lung collapse is more rapid after the pleura is opened than that in group D. The study also revealed that preemptive OLV did not increase the total OLV duration, considering that faster and better collapse quality may provide the surgeon with better visibility of the surgical space.

Excellent lung collapse can prevent surgeons from compressing lung tissue, thereby potentially reducing the incidence of postoperative pulmonary complications. To this end, we observed the effects of different OLV methods on pulmonary complication rates within three days after surgery. The diagnostic criterion we adopted for pulmonary complications was the European Perioperative Clinical Outcome (EPCO) standard. Compared to other scoring criteria, the EPCO score has higher sensitivity. However, there was no statistically significant difference ($P=0.19$).

There are several limitations to this trial. First, our study population excluded elderly patients (aged > 65 years), patients with an American Society of Anaesthesiologists classification > II, and patients with abnormal lung function. Some studies have reported that the rate of lung collapse depends on the quality of the lung itself, and further studies are needed to determine whether our results are applicable to the above high-risk patients. Second, a small sample size may limit the statistical significance and generalizability of the study results. Third, the evaluation of pulmonary complications was limited to 3 days after surgery due to the limitations of the discharge schedule, and our study is based on the use of DLT, the conclusions cannot be generalized to bronchial blockers.

Conclusion

Both the disconnection technique and preemptive one-lung ventilation shortened the time to satisfactory lung collapse. However, compared with the disconnection technique, preemptive one-lung ventilation results in superior lung collapse in the early stages and is therefore may more suitable for clinical application.

Abbreviations

OLV	one-lung ventilation
DLT	double-lumen tube
NVL	nonventilated lung
ASA	American society of Aneshesiologists physical status classification system
COPD	Chronic obstructive pulmonary disease
FOB	fibreoptic bronchoscope
TLV	Two-lung ventilation
PPCs	postoperative pulmonary complications
EPCO	European Perioperative Clinical Outcome

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-025-02899-1.

Additional file 1.

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Not applicable.

Authors' contributions

Conceived and designed the experiments: Z, H and W. Data collection: Z, X,M,F,S.Statistical analysis: Z. W and H acts as a guarantor and accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish. Z and X contributed equally to this work. All authors reviewed the manuscript.

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Data availability

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

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of the Daping Hospital of the Army Medical University (2022-Research-188) on July 12, 2022(No.10 ChangjiangZhilu, Yuzhong District, Chongqing 400042, China) and certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki.The study was registered at the https://www.chictr.org.cn/(29/07/2022, ChiCTR2200062199).

Consent for publication

The study was approved by the ethics committee of the Daping Hospital of the Army Medical University (2022-Research-188),Written informed consent was obtained from all the patients and consent for publication.If necessary, we can upload the informed consent forms.

Competing interests

The authors declare no competing interests.

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