Original Article

Partial pressure of oxygen control versus modified inflation-deflation method in identifying intersegmental plane during anatomical sublobectomy: a prospective, randomized, controlled trial

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Background: With increasing early-stage non-small cell lung cancer (NSCLC) diagnoses, sublobar resections including segmentectomy and wedge resection have become commonly used in clinical settings. The success of lung segment surgery hinges on the accurate identification of intersegmental planes (ISPs), which is typically achieved by the modified inflation-deflation method; however, this technique is associated with a prolonged duration for identifying ISP. The "partial pressure of oxygen control method" represents an optimization of the inflation-deflation technique, designed to facilitate rapid identification of ISP during surgical procedures. The present study was designed to assess the safety and effectiveness of the partial pressure of oxygen (PaO_2) control method for ISP identification in thoracoscopic anatomical sublobectomy, in comparison to the modified inflation-deflation method.

Methods: A total of 60 patients scheduled for thoracoscopic anatomical sublobectomy were randomly allocated into two groups: the intervention group (using the PaO_2 control method; n=30) and the control group (using the modified inflation-deflation method; n=30). The time to ISP appearance (T_{ISP}) was compared between these two groups. Arterial blood gas (ABG) levels were recorded at the following time points: prior to entry to operating room, during one-lung ventilation (OLV), upon completion of lung inflation, 3 minutes post-lung inflation, and 6 minutes post-lung inflation. Statistical analyses were conducted to evaluate the differences in operative time, intraoperative blood loss, incidence of postoperative complications, and average postoperative hospital stay.

Results: The T_{ISP} was significantly shorter in the intervention group than in the control group (307.0±108.3 *vs.* 496.7±154.0 seconds; P<0.001). Furthermore, the PaO_2 in the intervention group was significantly lower compared to the control group at 3 minutes following 100% oxygen administration (156.6±76.5 *vs.* 114.1±47.5 mmHg; P=0.01).

Conclusions: The PaO_2 control method facilitates more rapid acquisition of ISP compared to the modified inflation-deflation method, and it is deemed a safe and effective technique in thoracoscopic anatomical sublobectomy.

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Keywords: Early-stage non-small cell lung cancer (early-stage NSCLC); sublobectomy; intersegmental plane (ISP); partial pressure of oxygen control (PaO_2 control)

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Introduction

The increased use of low-dose spiral computed tomography (CT) has significantly enhanced the detection of pulmonary nodules, some of which are ultimately diagnosed as early-stage non-small cell lung cancer (NSCLC) (1). Moreover, thin-slice chest CT offers high-resolution imaging, further improving the accuracy and precision for early-stage lung cancer diagnosis (2). Clinical trials including JCOG 0802, JCOG 1211, and CALGB 140503 have demonstrated that sublobectomy confers improved short-term outcomes (e.g., overall postoperative recovery) in patients with early-stage NSCLC as it removes less lung tissue and preserves more pulmonary function (3-5). Moreover, its long-term outcomes, such as postoperative survival, are non-inferior to, and in some cases may even surpass, those achieved with conventional lobectomy. Anatomical sublobectomy encompasses several procedures, including anatomical segmentectomy, anatomical subsegmentectomy, and anatomical partial lobectomy (6,7). Anatomical sublobectomy focuses on bronchi and vessel identification, with the main challenge being the delineation and dissection of intersegmental planes (ISPs) (8). The modified inflation-deflation technique is a frequently employed method for identifying ISPs in clinical settings as it is easy to perform and requires no specialized equipment or instruments. However, it has not been ideal for thoracic surgeons due to the lengthy waiting periods required for the appearance of an ideal ISP. Hence, our team has innovatively introduced the partial pressure of oxygen (PaO_2) control method to facilitate rapid ISP identification. This new method involves maintaining a relatively low PaO_2 by controlling and adjusting the fraction of inspired oxygen (FiO_2) and the duration of ventilation during surgery, thereby quickly achieving the target PaO_2 and accelerating the appearance of ISP.

In our present study, patients scheduled for thoracoscopic anatomical sublobectomy were prospectively enrolled. By comparing the time to ISP appearance (T_{ISP}) between the modified inflation-deflation method and the PaO_2 control method, we validated the safety and effectiveness of the PaO_2 control method in identifying ISP during thoracoscopic anatomical sublobectomy. We present this article in accordance with the CONSORT reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-45/rc).

Highlight box

Key findings
- This study discovered that through the adjustment of the ventilator settings to decrease the patient's arterial blood gas partial pressure of oxygen (PaO_2) level, the formation of the intersegmental plane of the lung can be expedited.

What is known and what is new?
- The PaO_2 has an impact on the rate at which the intersegment plane is formed.
- This approach does not necessitate any extra equipment or incur additional costs. Moreover, it is capable of expediting the formation of inter-segmental planes.

What is the implication, and what should change now?
- Partial pressure of oxygen control method is a safe and effective technique in thoracoscopic anatomical sublobectomy, and deserves wider adoption.

Methods

Study design

This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of The Second Affiliated Hospital of Air Force Medical University (Tangdu Hospital, Fourth Military Medical University) (ethical approval number: K202406-24). This is a two-parallel study, all participants enrolled in the study provided written informed consent. Patients who underwent thoracoscopic anatomical sublobectomy in the Department of Thoracic

Surgery at The Second Affiliated Hospital of Air Force Medical University between May 2024 and July 2024 were selected as the participants.

The inclusion criteria were as follows: (I) aged 18–75 years; (II) an Eastern Cooperative Oncology Group (ECOG) performance status (PS) score of 0 or 1; (III) thin-slice CT revealed a maximum tumor diameter of ≤2.0 cm, and the consolidation tumor ratio (CTR) was within the range of <1.0.

The exclusion criteria were as follows: (I) CTR =1, pure solid nodule; (II) prior history of lung surgery; (III) comorbid interstitial pneumonia, multiple giant pneumatoceles, pulmonary fibrosis, or severe emphysema; (IV) conversion to thoracotomy due to various reasons or changing the surgical plan during the operation; and (V) inability to understand/cooperate or refusal to sign the informed consent form regarding the study protocol.

All the enrolled patients were required to undergo a thin-slice CT scan prior to surgery, during which three-dimensional CT bronchography and angiography (3D-CTBA) was performed to locate the lesions and obtain the three-dimensional (3D) architecture of adjacent structures. In adherence to the principles of achieving precise anatomical excision, simplifying surgical procedures, and minimizing tissue damage, the extent of lung segment resection was adjusted and defined (ensuring that the resection margin was ≥2 cm or larger than the diameter of the tumor) for developing an individualized optimal surgical protocol. All the surgeries were performed by the same surgical team at the department of thoracic surgery of our center.

Sample size calculation

Sample size was calculated according to the results of a preliminary study, which was carried out in 19 patients undergoing thoracoscopic sublobectomy at the department of thoracic surgery of our hospital from 15 April to 15 May, 2024.

When the PaO_2 control method was applied intraoperatively, the average time for the appearance of an ideal and clearly visible ISP (grade 3) was 332.3 seconds; in contrast, when the modified inflation-inflation method was employed, the average time for the appearance a grade 3 ISP was 480.0 seconds. The sample size was estimated using the PASS 15.0 software (NCSS Statistical Software, Kaysville, UT, USA), which yielded a requirement of 24 cases per group, totaling 48 cases, based on a two-tailed test with parameters set as follows: mean time for group 1 ($\mu 1$) =332.3 seconds, mean time for group 2 ($\mu 2$) =480.0 seconds, significance level (α) =0.05, power ($1 - \beta$) =0.80, and a ratio of N1:N2 =1. In consideration of potential attrition or exclusion of cases, a total of 60 cases were ultimately enrolled, with 30 cases allocated to each group (*Figure 1*).

Randomization

The eligible participants were encoded based on the sequence of their admission and then randomly allocated to either the intervention group (using PaO_2 control method) or the control group (using the modified inflation-deflation method) in a 1:1 ratio by utilizing a random number table method.

Surgical selection

All patients underwent double-lumen endotracheal tube placement and received general anesthesia. During the surgery, one-lung ventilation (OLV) was performed on the healthy side. The patient was placed in the lateral decubitus position, with the operative side facing up. A dual micro-port thoracoscopic surgery developed by our team (9) was applied, during which the primary operating port was established at the 4th intercostal space along the anterior axillary line. For procedures involving the middle lobe of the right lung, the 3rd intercostal space along the anterior axillary line was selected. The incision was approximately 2 cm in length, and an incision protector was used to support the skin and muscle tissue. The auxiliary operating port was created at the 7th or 8th intercostal space along the posterior axillary line, measuring about 0.5 cm in length. The observation port was placed at the 7th intercostal space of the midaxillary line, with a length of approximately 5–10 mm. A 5–10-mm trocar was directly inserted into the observation port through the intercostal space.

Surgical procedures

Control group (using the modified inflation-deflation method)

Watershed analysis of the target pulmonary artery was performed based on preoperative 3D-CTBA findings to locate the lesions and decide the resection range. Following the ligation occluded of the target pulmonary artery, the anesthesiologist manually administered 100% oxygen to both lungs, maintaining an airway pressure of

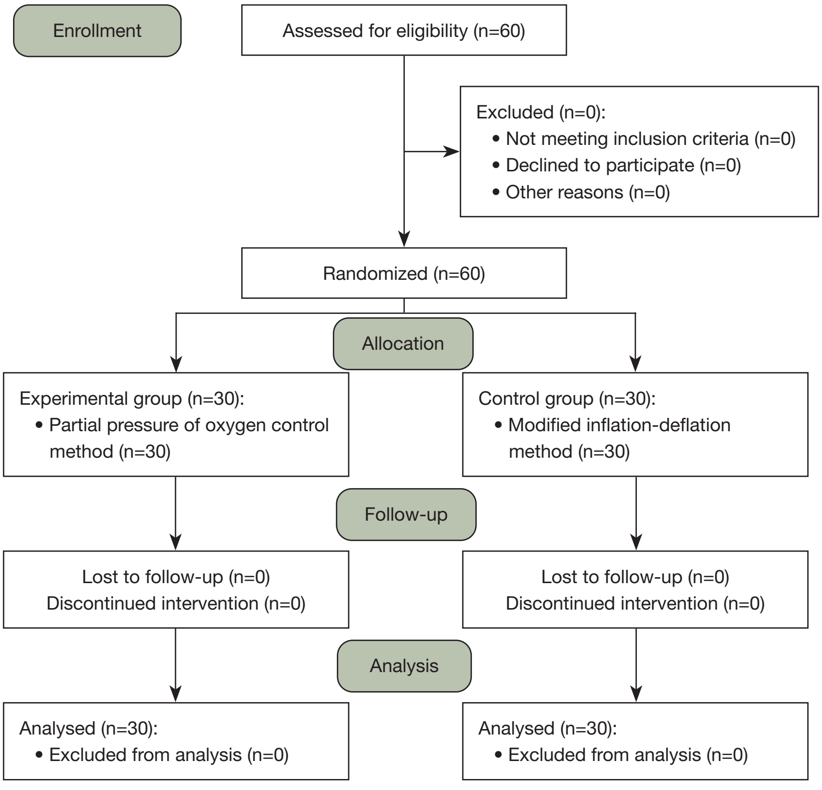

Figure 1 The study flow diagram.

approximately 20 cmH_2O to ensure complete inflation of the operated lung. The airway at the surgical side was then opened, and OLV was resumed on the healthy side, allowing the preserved lung tissue to deflate, which created a distinct boundary with the inflated lung tissue, identified as the ISP. Finally, the ISP was dissected using the "Inserted Multilateral Cutting Method", an innovative technique for managing the inter-segmental plane. To ensure proper alignment, the thin surface of the linear cutter stapler was carefully inserted directly into the lung parenchyma along the intersegmental vein and the ISP. The insertion extended from the hilum to the distal region, allowing precise excision of the tumor-containing lung tissue.

Intervention group (using PaO_2 control method)

Following the initiation of OLV on the healthy side, the initial inspired oxygen fraction (FiO_2) was set at 50%. The FiO_2 was subsequently adjusted based on the peripheral arterial oxygen saturation (SpO_2) value, with the aim of maintaining SpO_2 at approximately 95%. According to the preoperative reconstruction, the location of the lesion and the scope of resection were determined through the arterial watershed analysis. The target pulmonary artery or bronchus was occluded, and the anesthesiologist manually controlled the administration of 100% oxygen to the operative side of the lung, maintaining an airway pressure of approximately 20 cmH_2O until the operative lung was fully inflated. The ventilator was then disconnected, and both airways were opened to allow communication with the atmosphere. The surgeon applied a cotton ball to compress the preserved lung tissue and observed the SpO_2 value. When it dropped to 95%, OLV was initiated on the healthy side with an initial FiO_2 of 50%. The FiO_2 was adjusted according to the SpO_2 value to maintain SpO_2 at approximately 95%. The demarcation between the deflated lung tissue and the inflated target lung tissue formed the ISP. Again, the ISP was dissected using the "Inserted Multilateral Cutting Method".

Measurements

The primary outcome measured was the T_{ISP} (i.e., lung collapse exceeded grade 3). The T_{ISP} was defined as the duration from the termination of 100% oxygen administration to the time point at which ISP appeared and was marked. The lung collapse was scored according to the modified Bussiers criteria (10), which involves a visual and subjective descriptive evaluation and includes considerations of the extent of lung collapse, space in the thoracic cavity, atelectasis, coloring of the lungs (with healthy lungs appearing pink-grey to purple), and surgeon satisfaction with the collapse. The lung collapse scoring system was as follows: 1 point: no lung collapse; 2 points: collapse affecting no more than half of the lung tissue; 3 points: collapse affecting more than half of the lung tissue; and 4 points: total lung collapse. Each surgical video clip was independently assessed by two researchers (M.X. and H.L.) who were blinded to the grouping status. Discrepancies were resolved through consensus. A lung collapse score of 3 or 4 was deemed an ideal and clearly visible ISP, and the lung tissue was then resected along the demarcated boundary. When the score was 1–2 points, the surgeon proceeded to dissect the target lung segment along the demarcated boundary and intersegmental veins after a waiting period of 15 minutes. The secondary outcomes included operative time, intraoperative blood loss, rate of conversion to thoracotomy, mortality, duration of chest tube drainage, volume of postoperative drainage, incidence of postoperative complications (e.g., pneumonia, air leak, and hemoptysis), postoperative hospital stay, and total hospitalization cost. Arterial blood was sampled at multiple points [before entry to operating room, after OLV (with SpO_2 maintained at 95%), after 100% oxygen administration, and 3 and 6 minutes after 100% oxygen administration] to assess pH, arterial oxygen saturation (SaO_2), PaO_2 and partial pressure of carbon dioxide ($PaCO_2$).

Statistical analysis

Data analysis was conducted using SPSS 29.0 statistical software (IBM Corp., Armonk, NY, USA). Normally distributed measurement data were presented as the mean ± standard deviation (mean ± SD) and compared using the *t*-test. Non-normally distributed measurement data were reported as median (P25, P75), and their comparisons were made using the rank-sum test. Count data were presented in cases (%) and compared using Chi-squared tests. $P<0.05$ was considered statistically significant.

Results

Baseline data

A total of 60 patients were enrolled in this study (*Table 1*), and all patients were randomly allocated in a 1:1 ratio to the intervention group and the control group (*Figure 1*). These two groups showed no statistically significant differences in the preoperative baseline data including age, gender, height, weight, body mass index (BMI), smoking history, lung disease history, lung function, red blood cell (RBC) count, hemoglobin level, tumor location, and tumor diameter. Only the CTR was significantly higher in the intervention group than in the control group [0.35 (0.20–0.63) *vs.* 0.25 (0.00–0.43); P=0.04].

Indicators before and after treatment

The intervention group had significantly shorter T_{ISP} than the control group (307.0±108.3 *vs.* 496.7±154.0 seconds; P<0.001) (*Figure 2*). Furthermore, the intervention group had significantly lower PaO_2 at 3 minutes after 100% oxygen administration (156.6±76.5 *vs.* 114.1±47.5 mmHg; P=0.01) and significantly higher pH (7.32±0.05 *vs.* 7.35±0.05; P=0.03) than the control group. PaO_2 significantly differed between these two groups before admission to operating room (P<0.05), whereas no significant differences were found in pH, $PaCO_2$, and SaO_2 at other time points (*Figure 3*).

Range of surgical resection

The details regarding the range of surgical resection are provided in *Table 2*. Among the 60 patients, 27 underwent resection with lung segments as the surgical unit, among whom 4 patients received combined segmentectomy and 23 patients underwent resection of a single lung segment. In addition, 33 patients underwent resection with subsegments as the smallest surgical unit, with 17 undergoing subsegmentectomy for a single segment and 16 patients undergoing combined subsegmentectomy.

Surgical outcomes

The two groups exhibited comparable operative time, intraoperative blood loss, number of lymph nodes resected, postoperative drainage volume, duration of thoracic

Table 1 Baseline data of patients

Variables	Intervention group (n=30)	Control group (n=30)	P
Age (years)	56.4±11.2	55.2±12.4	0.69
Gender			0.78
Male	10 (33.3)	9 (30.0)	
Female	20 (66.7)	21 (70.0)	
Height (m)	1.64 (1.60–1.72)	1.63 (1.60–1.70)	0.84
Weight (kg)	64.9±10.6	63.6±10.7	0.91
Body mass index (kg/m^2)	23.5±2.4	24.6±3.5	0.15
Smoking history	5 (16.7)	6 (20.0)	0.74
Lung disease	5 (16.7)	2 (6.7)	0.42
Pulmonary function			
FEV1 (%)	78.0±6.3	82.7±15.5	0.13
MVV (%)	97.5±26.3	93.5±15.6	0.48
Routine blood test			
Hemoglobin (g/L)	140.8±12.7	136.9±12.9	0.25
Red blood cells (×10^{12}/L)	4.6±0.4	4.4±0.4	0.09
Location type			0.27
Peripheral	22 (73.3)	18 (60.0)	
Central	8 (26.7)	12 (40.0)	
Nodule location			0.89
RUL	10 (33.3)	10 (33.3)	
RML	0 (0.0)	1 (3.3)	
RLL	6 (20.0)	7 (23.3)	
LUL	9 (30.0)	6 (20.0)	
LLL	5 (16.7)	6 (20.0)	
Nodule diameter (mm)	12.9±4.4	12.1±4.2	0.52
CTR	0.35 (0.20–0.63)	0.25 (0.00–0.43)	0.04

Data are expressed in mean ± SD, n (%) or median (IQR). CTR, consolidation tumor ratio; FEV1, forced expiratory volume in 1 second; IQR, interquartile range; LLL, left lower lobe; LUL, left upper lobe; MVV, maximal voluntary ventilation; RLL, right lower lobe; RML, right middle lobe; RUL, right upper lobe; SD, standard deviation.

catheterization, and postoperative hospital stay (all P>0.05) (*Table 3*). The pathological diagnoses of the primary lesions post-surgery were as follows: adenocarcinoma *in situ* (n=16), minimally invasive adenocarcinoma (n=21), invasive adenocarcinoma (n=22), and benign hamartoma (n=1) (*Table 3*).

Postoperative complications

9 patients in the intervention group experienced perioperative complications including wound pain (n=2), hemoptysis (n=3), pneumonia (n=1), chest hemorrhage (n=1), abdominal distension (n=1), and acute heart failure (n=1). In the control group, 6 patients experienced

perioperative complications, comprising 3 cases of pain, 1 case of hemoptysis, 1 case of pneumonia, and 1 case of air leak. All patients recovered well after conservative treatment. There was no statistically significant difference in the incidence of complications between these two groups (*Table 4*).

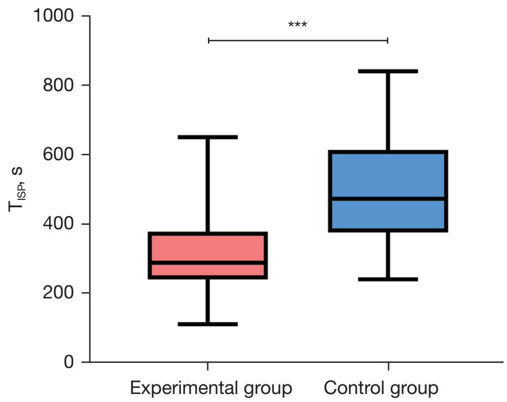

Figure 2 The appearance time of the T_{ISP} between two groups. ***, P<0.001. ISP, intersegmental plane; T_{ISP}, time to ISP appearance.

Discussion

In 2006, the US National Comprehensive Cancer Network (NCCN) guidelines for lung cancer diagnosis and treatment formally recognized thoracoscopic lobectomy as a standard surgical approach for early-stage NSCLC for the first time (11). However, recent studies have indicated that sublobectomy has comparable effectiveness to lobectomy in the treatment of stage IA NSCLC. In addition to similar survival outcomes, sublobectomy has been associated with reduced perioperative morbidity and mortality, as well as enhanced preservation of lung function. Sublobar surgeries, represented by anatomical segmentectomy, were reaffirmed by the Version 3.2024 NCCN guidelines as a recommended surgical approach for lung nodules measuring up to 2 cm in size (12).

The precise delineation of ISP is a pivotal and challenging aspect of anatomical sublobectomy. In fact, an imprecise interface between segments may result in inadequate resection of the target segment, thereby compromising the safe margins of the operation. This can adversely impact oncological outcomes and may lead to postoperative complications including air leak, atelectasis, and

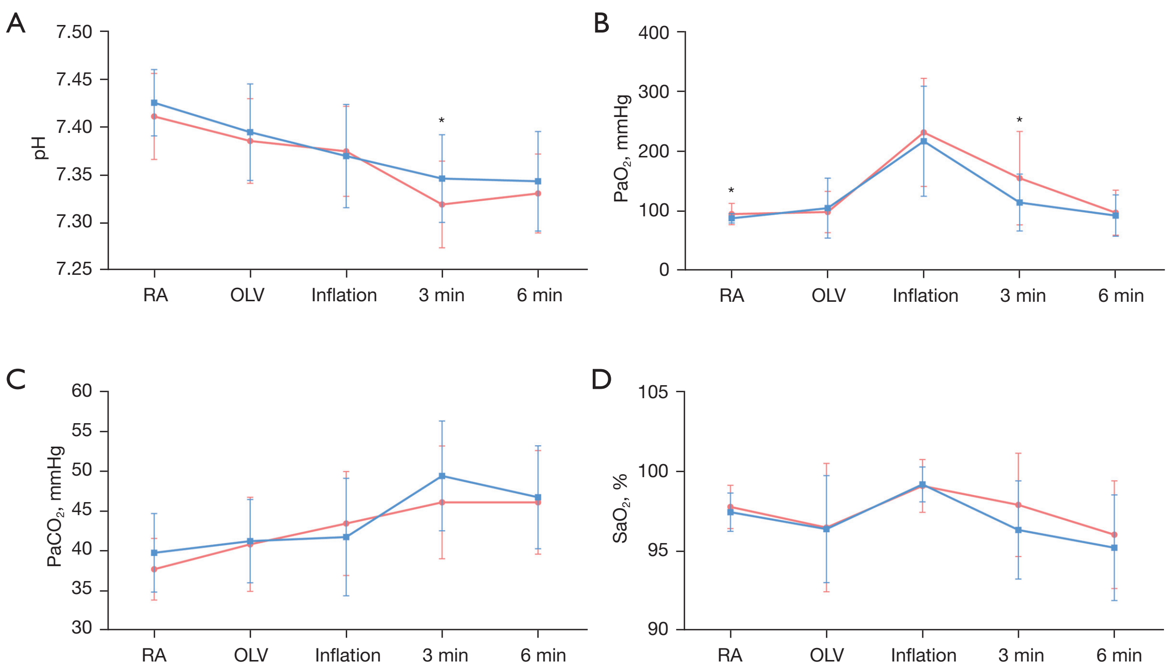

Figure 3 Mean pH (A), PaO_2 (B), $PaCO_2$ (C), and SaO_2 (D) values for the patients randomized to the intervention or control group. Red (control group): modified expansion-collapse method, Blue (intervention group): partial pressure control of oxygen group, measured while breathing RA, OLV before lung expansion, inflation, 3 min and 6 min after the lung expansion. *, P<0.05. OLV, one-lung ventilation; $PaCO_2$, partial pressure of carbon dioxide; PaO_2, partial pressure of oxygen; RA, room air; SaO_2, arterial oxygen saturation.

Table 2 Location of the resected segments

Locations	Intervention group (n=30)	Control group (n=30)	Total
RUL	10	10	20
S1	1	1	2
S1a	0	1	1
S1 + S2	1	1	2
S1 + S2a	1	0	1
S1a + S2	1	0	1
S2	1	1	2
S2a	0	1	1
S2a + S3b	0	1	1
S2b	1	0	1
S2b + S3a	0	1	1
S3	1	1	2
S3a	3	2	5
RML	0	1	1
RS5	0	1	1
RLL	6	7	13
S6	0	2	2
S6 + S10a	1	0	1
S6 + S8a	1	0	1
S8	2	1	3
S8a + S9a	0	2	2
S8 + S9	1	0	1
S8b	0	1	1
S9 + S10	1	0	1
S9a	0	1	1
LUL	9	6	15
S1+2c + S3a + S4	1	0	1
S1+2c + S4a	0	1	1
S1+2	2	0	2
S1+2a	1	0	1
S1+2a + S3c	0	1	1
S1+2ab	1	2	3
S1+2bc	0	1	1
S3	2	0	2
S3b	1	0	1
S3c	0	1	1
S4+5	1	0	1
LLL	5	6	11
S6	2	2	4
S6b	1	1	2
S8	1	0	1
S8a	0	2	2
S8a + S9a	0	1	1
S9	1	0	1

Right: S1, apical segment; S2, posterior segment; S3, anterior segment; S4, lateral segment; S5, medial segment; S6, superior segment; S7, medial-basal segment; S8, anterior-basal segment; S9, lateral-basal segment; S10, posterior-basal segment. Left: S1+2, apico-posterior segment; S3, anterior segment; S4, superior lingular segment; S5, inferior lingular segment; S6, superior segment; S8, anterior-basal segment; S9, lateral-basal segment; S10, posterior-basal segment. RLL, right lower lobe; RML, right middle lobe; RUL, right upper lobe; LLL, left lower lobe; LUL, left upper lobe.

hemoptysis (13). Currently, several clinical methods are employed to identify ISP: the traditional inflation-deflation method, the modified inflation-deflation method, the target bronchial ventilation method, and the near-infrared fluorescence imaging using indocyanine green (14), among which the modified inflation-deflation technique is the most widely utilized for identifying ISP as it is relatively simple and requires no specialized equipment (8). Following the complete separation and ligation of the bronchus, artery, and veins in the target segment, positive pressure ventilation is offered at a pressure of 20 cmH_2O to inflate the affected lung. Subsequently, OLV is performed on the healthy lung. The difficulty for gas in the target segment to escape through the pulmonary circulation or airway facilitates the visualization of ISP (15,16). Multiple studies have demonstrated that this method can reliably and accurately delineate ISP. Unfortunately, it typically requires 5–12 minutes to achieve a clear visualization of ISP, which will prolong the surgery (17,18). Yang *et al.* employed nitrous oxide (N_2O) to expedite the absorption of gas in the alveoli by mixing

Table 3 Perioperative characteristics

Variables	Intervention group (n=30)	Control group (n=30)	P
Operating time (min)	111.0 [89.5–139.5]	105 [89.5–117.5]	0.41
Bleeding volume (mL)	50 [20–50]	30 [20–50]	0.38
No ventilation time (s)	177.5 [118.75–224.25]		
T_{IPS} (s)	307.0±108.3	496.7±154.0	<0.001
Lymph node methods			0.002
No	5 (16.7)	0 (0.0)	
Sampling	21 (70.0)	30 (100.0)	
Dissection	4 (13.3)	0 (0.0)	
Number of lymph node	4 [1.75–8]	3.5 [1.75–5]	0.21
Drainage volume (mL)	290 [205–642.5]	330 [165–600]	0.95
Drainage time days	3 [2–3.25]	3 [2–4]	0.92
Postoperative hospital stay (d)	4 [4–5]	4 [3–5]	0.80
Pathology			0.33
AIS	7 (23.3)	9 (30.0)	
MIA	9 (30.0)	12 (40.0)	
IAC	14 (46.7)	8 (26.7)	
Benign	0 (0.0)	1 (3.3)	

Data are expressed in mean ± SD, n (%) or median [IQR]. AIS, adenocarcinoma in situ; IAC, invasive adenocarcinoma; IQR, interquartile range; MIA, microinvasive adenocarcinoma; SD, standard deviation; T_{IPS}, time of intersegmental plane.

Table 4 Postoperative complications

Variables	Intervention group (n=30)	Control group (n=30)	P
Postoperative complications (grade ≥2)	9	6	0.37
Wound pain	2	3	
Hemoptysis	3	1	
Pneumonitis	1	1	
Air leak	–	1	
Pleural hemorrhage	1	–	
Abdominal distension	1	–	
Heart failure	1	–	

Data are expressed in n.

it with the inhaled gas, thereby accelerating lung collapse. This method can be integrated with the modified inflation-deflation technique to further shorten the time to ISP visualization without compromising arterial oxygenation in patients undergoing OLV. Nevertheless, the safety of using N_2O in thoracoscopic segmentectomy warrants further investigations. Indocyanine green fluorescence can rapidly and accurately obtain an ideal ISP within 1–2 minutes. However, due to shortcomings such as limited imaging time, high requirements for equipment and costs, and the existence of allergic risk, it needs further optimization and improvement.

Lung collapse occurs in two distinct stages, each driven by different mechanisms (19). Stage 1, known as the rapid collapse phase, is characterized by the rapid collapse of the lungs due to the intrinsic elastic recoil, which occurs immediately following the opening of the pleura. However, this process typically concludes within 60 seconds due to the closure of the small airways. Some authors have used a suction tube to remove residual gas from the lung tissue on the affected side, with an attempt to speed up lung collapse (20). However, the operating habits vary among different anesthesiologists, and it is difficult to achieve consistency in the anesthesia practices. In our practice, we opened bronchi at both sides immediately after 100% oxygen administration to allow communication with the atmosphere; meanwhile, we used cotton ball to compress the lung tissue that remained inflated, thereby expediting gas expulsion and facilitating the rapid collapse of the lung tissue. Stage 2 is the slow deflation phase, marked by the closure of small airways, cessation of passive deflation, and absorption of residual gas within the lungs. Physiologically, there is a minimal amount of oxygen dissolved physically in the plasma. The majority of oxygen is chemically bound to hemoglobin, forming oxyhemoglobin that is instrumental in the process of oxygen transport. PaO_2 determines both the quantity of oxygen physically dissolved in the blood and the capacity of hemoglobin to bind oxygen. By adjusting FiO_2 and ventilation time we optimized PaO_2 levels to facilitate faster ISP formation. This method promotes rapid lung tissue collapse and expedites the establishment of a clear ISP. Evidence indicates that factors affecting the rate of lung collapse include age, preoperative lung function, target lung volume/total lung volume, and intraoperative PaO_2; moreover, the ISP appearance is faster in patients with low intraoperative PaO_2 (17). In our present study, because excluding patients with poor lung function, underlying pulmonary diseases, and a history of pulmonary surgery, all the remaining patients achieved an ideal and clearly visible ISP. The PaO_2 control method significantly shortened the T_{ISP} when compared to the modified inflation-deflation method (307.0±108.3 *vs.* 496.7±154.0 seconds; $P<0.001$). The essence of this technique lies in disconnecting the ventilator immediately after the lung is inflated with 100% oxygen and opening both bronchi to allow communication with the atmosphere. Concurrently, the surgeon uses a cotton ball to compress the preserved lung tissue to accelerate the expulsion of gas and foster the rapid collapse of the lung tissue. On the other hand, the initial FiO_2 value is set at 50% at the commencement of the operation. During the procedure, the FiO_2 is adjusted in accordance with the SpO_2 value, with the aim of maintaining SpO_2 at approximately 95%. This strategy, coupled with the maintenance of a relatively low PaO_2, further expedites the collapse of the lung tissue. In our current study, the observed reduction in PaO_2 in the intervention group (compared to the control group) at 3 minutes post-lung inflation corroborated this approach. Correlation analysis revealed that the RBC count and PaO_2 value at the 6th minute were associated with T_{ISP}: a higher RBC count and a lower PaO_2 value at the 6th minute led to a shorter T_{ISP}.

Our present study has several limitations. First, there is no objective or standardized method for quantifying ISP, and ISP grading is predominantly reliant on the subjective visual assessment of the operator, leading to potential observer bias and variability in the results. Future research should consider the development of standardized criteria or advanced imaging technologies, such as artificial intelligence-based grading systems, to improve the consistency and reliability of ISP evaluation.

Second, only patients with good lung function were enrolled in our current study. The exclusion of individuals with chronic lung diseases, such as chest adhesions and emphysema, limits the generalizability of our findings. Patients with compromised pulmonary function or complex anatomical variations may experience significantly different outcomes when using this method.

Third, we did not assess the impact of the PaO_2 control method on long-term outcomes, such as postoperative lung function or survival.

Fourth, our study was limited by its small scale and single-center design, and the safety and effectiveness of the PaO_2 control method need to be further validated in large-scale multicenter studies.

Lastly, while we reported no major adverse events in the current cohort, we did not conduct a detailed safety analysis of the oxygen control method, such as potential risks of hypoxemia or related intraoperative complications. Future studies should incorporate systematic monitoring and reporting of these safety metrics to establish thresholds for safe oxygen level manipulation during surgery.

Conclusions

In summary, the PaO_2 control method can be utilized for the rapid identification of ISP during thoracoscopic anatomical sublobectomy, although its specific mechanism, influential factors, and long-term effects on patients warrant further research.

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Footnote

Reporting Checklist: The authors have completed the CONSORT reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-45/rc

Trial Protocol: Available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-45/tp

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-2025-45/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Ethics Committee of The Second Affiliated Hospital of Air Force Medical University (Tangdu Hospital, Fourth Military Medical University) (ethical approval number: K202406-24). All participants enrolled in the study provided written informed consent.

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