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The effect of laryngeal mask combined with bronchial occluder in patients undergoing single lung ventilation in thoracic surgery

A retrospective study

Wanling Wang, MM[a], Yanbin Sun, MM[a], Zhenru Zhao, MM[a], Jiao Guan, MM[a,*]

Abstract

This study evaluates the clinical efficacy of combining a laryngeal mask airway with a bronchial blocker (LMA-BB) in single-lung ventilation (OLV) during thoracic surgery compared to the traditional single-lumen tracheal tube with a bronchial blocker (single-lumen tracheal tube [SLT] + BB). A retrospective analysis was performed on 93 patients undergoing thoracic surgery with OLV from December 2021 to September 2023. After propensity score matching (1:1), 34 patients remained in each group (LMA-BB and SLT + BB). Key outcomes, including airway pressures, ventilation and oxygenation parameters, lung compliance, postoperative recovery, and complications, were compared between groups. After matching, the 2 groups had similar baseline characteristics. The LMA-BB group showed significant advantages in airway pressure management, with lower peak and plateau pressures ($P < .05$). Ventilation and oxygenation efficiency were superior in the LMA-BB group, including lower end-tidal carbon dioxide (37.8 ± 4.7 vs 39.2 ± 5.1 mm Hg, $P = .04$) and higher oxygenation index (255 ± 22 vs 245 ± 28, $P = .04$). Lung compliance was improved ($P = .018$), and more patients in the LMA-BB group achieved excellent lung collapse (76.5% vs 52.9%, $P = .032$). Additionally, postoperative recovery was faster, with shorter extubation times (12.4 ± 3.2 vs 14.8 ± 3.6 minutes, $P = .003$) and fewer complications, including hypoxemia (5.9% vs 23.5%, $P = .027$) and pulmonary issues (8.8% vs 20.6%, $P = .046$). The LMA-BB technique offers significant clinical benefits over the traditional SLT + BB method in thoracic OLV, including improved airway management, ventilation efficiency, lung compliance, and faster recovery. It also reduces postoperative complications, making it a promising alternative for thoracic surgery.

Abbreviations: ASA = American Society of Anesthesiologists, BMI = body mass index, DBP = diastolic blood pressure, EtCO2 = end-tidal carbon dioxide, HR = heart rate, LMA-BB = laryngeal mask airway with a bronchial blocker, MAP = mean arterial pressure, OI = oxygenation index, OLV = single-lung ventilation, PSM = propensity score matching, SBP = systolic blood pressure, SLT = single-lumen tracheal tube.

Keywords: airway management, bronchial blocker, laryngeal mask airway, single-lung ventilation, thoracic surgery

1. Introduction

Single lung ventilation (OLV) is a key technique to achieve surgical side lung collapse and improve surgical field of view in thoracic surgery, and is widely used in lobectomy, segmentectomy and thoracoscopic lung surgery. However, traditional methods of single lung ventilation mainly rely on single lumen tracheal catheter combined with bronchial occluder or double lumen bronchial catheter.[1–4] Although double lumen bronchial catheter can independently ventilate both lungs and facilitate discharge, its large tube diameter and rigidity increase the difficulty of intubation, which can lead to vocal cord injury and postoperative complications, such as hoarse voice and sore throat. In contrast, bronchial occluders combined with single lumen catheters have obvious advantages in terms of ease of operation and reduction of airway damage, especially for patients with difficult airways.[5–7] However, most of the existing studies focus on the application of a single tool, and the systematic evaluation of laryngeal mask combined with bronchial occlusive device in single lung ventilation is lacking, especially the applicability and long-term safety in different patient groups are unclear.[8,9] This study hypothesized that laryngeal mask combined with bronchial occlude (LMA-BB) can achieve lower airway pressure, better

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

[a] Department of Anesthesiology, Chengde Central Hospital, Chengde, Hebei, P.R. China.

* Correspondence: Jiao Guan, Department of Anesthesiology, Chengde Central Hospital, Chengde, Hebei 067000, P.R. China (e-mail:19903240345@163.com).

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ventilation and oxygenation effect, more stable hemodynamic status, better lung compliance and better quality of lung collapse during single lung ventilation in thoracic surgery compared with traditional single-lumen tracheal tube [SLT] + BB method, thus reducing postoperative complications. Promote rapid recovery of patients. Based on this, the purpose of this study was to compare the clinical effects of LMA-BB group and SLT + BB group in airway pressure management, ventilation and oxygenation effects, hemodynamic stability, lung function and postoperative recovery through retrospective analysis, and to evaluate the application value of laryngeal mask combined with bronchial occluders in optimizing single lung ventilation in thoracic surgery. The aim is to provide empirical evidence for the improvement of airway management strategies, improve surgical safety and postoperative rehabilitation quality of patients.

2. Methods

2.1. Study subjects

This study was approved by the Ethics Committee of Chengde Central Hospital. We conducted a retrospective analysis of 93 patients who underwent single-lung ventilation (OLV) surgery at our hospital between December 2021 and September 2023. The inclusion and exclusion criteria were carefully applied to ensure that only patients who met the requirements for the study were enrolled. The patients were divided into 2 groups based on their previous anesthesia methods. The experimental group (LMA-BB group) included 36 patients who received a laryngeal mask airway (LMA) combined with a bronchial blocker for OLV. The control group (SLT + BB group) consisted of 57 patients who underwent the traditional method, which involved a SLT combined with a bronchial blocker for OLV. To ensure comparability between the 2 groups, propensity score matching (PSM) was applied. After matching, 34 patients from each group were selected for further analysis, ensuring that both groups were well-balanced in terms of baseline characteristics and preoperative factors.

2.2. Inclusion criteria

(1) Age: 18 to 65 years. (2) American Society of Anesthesiologists (ASA) classification: grade I to III. (3) Underlying conditions: Patients undergoing thoracic OLV surgeries (e.g., lobectomy, segmentectomy, wedge resection, video-assisted thoracic surgery, etc). (4) Preoperative imaging confirmed indications for OLV (e.g., pulmonary tumors, localized emphysema, pulmonary bullae, pleural effusion, bronchiectasis, etc). (5) Surgical procedure: Open thoracic surgery or thoracoscopic minimally invasive surgery requiring OLV, with successful completion of OLV. (6) Anesthesia method: After induction of general anesthesia, OLV was achieved using either a laryngeal mask airway combined with a bronchial blocker (LMA-BB) or a single-lumen tracheal tube combined with a bronchial blocker (SLT + BB). Anesthesia management followed the hospital's standard protocols, including the use of muscle relaxants, monitoring of anesthesia depth, and airway pressure monitoring. (7) Preoperative and postoperative information: Complete records of airway management and OLV-related data (e.g., airway pressure, arterial blood gas analysis, oxygenation index [OI]) were available preoperatively and postoperatively. Patients were successfully extubated postoperatively without the need for reintubation. Follow-up data were complete.

2.3. Exclusion criteria

(1) Airway management-related issues: Presence of anatomical airway abnormalities (e.g., subglottic stenosis, tracheal tortuosity or deformation, significant glottic insufficiency) that could affect the placement of the LMA or bronchial blocker. Patients with a preoperative diagnosis of high aspiration risk (e.g., gastroesophageal reflux disease, incomplete gastric emptying). (2) Concurrent infections or diseases: Active pulmonary tuberculosis or other severe respiratory infections that could affect OLV or postoperative lung function assessment. Patients with uncontrolled systemic infections (e.g., sepsis, bacteremia) or inflammatory states (e.g., acute pancreatitis). (3) Perioperative medication or treatment interventions: Patients receiving high-dose steroids or immunosuppressants preoperatively that could interfere with postoperative lung function recovery. Patients requiring extracorporeal circulation or other cardiopulmonary support techniques due to indications for other surgeries. (4) Severe intraoperative complications: Presence of severe complications during surgery (e.g., massive hemorrhage, pneumothorax) that could interfere with the study. (5) Special patient populations: Pregnant or breastfeeding women. Patients with advanced malignant tumors with multiple metastases or those unsuitable for active treatment.

2.4. Procedure

2.4.1. Laryngeal mask airway combined with bronchial blocker (LMA-BB group).

Preoperative preparation: Patients were routinely fasted for 8 hours before surgery. An intravenous access was established, and monitoring of electrocardiogram, noninvasive blood pressure, and oxygen saturation (SpO_2) was initiated. Patients received standard oxygen supplementation and underwent induction of general anesthesia using the following medications: propofol 2 mg/kg, sufentanil 0.2 to 0.4 μg/kg, and rocuronium bromide 0.6 mg/kg. Once complete muscle relaxation was achieved, airway management was performed.

LMA insertion: An appropriately sized laryngeal mask airway was selected and lubricated. The LMA was inserted along the hard palate in an arc-shaped manner, ensuring a good seal above the glottis. Ventilation was tested using the anesthesia machine to confirm adequate lung ventilation.

Bronchial blocker insertion: A fiberoptic bronchoscope (≤4 mm in diameter) was inserted through the LMA to guide the placement of the bronchial blocker into the target bronchus (surgical lung). The cuff of the bronchial blocker was positioned within the target bronchus and inflated to occlude the bronchial lumen.

Single-lung ventilation adjustment: The position of the LMA and bronchial blocker was adjusted to ensure proper ventilation of the contralateral lung. A fiberoptic bronchoscope was used to verify the stability of the bronchial blocker's position and confirm complete collapse of the surgical lung. Single-lung ventilation parameters were set as follows: tidal volume 6 to 8 mL/kg, respiratory rate 10 to 20 breaths/min, inspired oxygen concentration (FiO_2) 50% to 100%, maintaining adequate oxygenation ($SpO_2 \geq 92\%$).

2.4.2. Control group procedure: single-lumen tracheal tube combined with bronchial blocker (SLT + BB group).

Preoperative preparation: Identical to the experimental group, including fasting, establishment of intravenous access, and induction of general anesthesia using propofol, sufentanil, and rocuronium bromide.

Single-lumen tracheal tube insertion: An appropriately sized single-lumen tracheal tube (typically 7.0 or 7.5 mm internal diameter) was selected. After complete muscle relaxation, the tracheal tube was inserted through the vocal cords into the trachea. The tube was secured, and ventilation was tested using the anesthesia machine to ensure unobstructed ventilation.

Bronchial blocker insertion: A fiberoptic bronchoscope was inserted through the single-lumen tracheal tube to guide the placement of the bronchial blocker into the target bronchus (surgical lung). The cuff of the bronchial blocker was inflated to fully occlude the target bronchus.

Single-lung ventilation adjustment: The position of the bronchial blocker was confirmed to be stable, and the collapse of the surgical lung was verified using the fiberoptic bronchoscope. Single-lung ventilation parameters were adjusted to match those of the experimental group, ensuring adequate ventilation of the contralateral lung and maintaining safe oxygenation levels.

Both groups continuously monitored airway pressure, end-tidal carbon dioxide partial pressure, and oxygen saturation (SpO_2) throughout the procedure. The pressure and position of the bronchial blocker cuff were adjusted in real-time as needed. If the position of the bronchial blocker changed, fiberoptic bronchoscopy was promptly used to reposition it.[10,11]

2.4.3. Data collection. The study involved collecting comprehensive data on a variety of clinical parameters. These included baseline characteristics, intraoperative airway pressures, ventilation and oxygenation parameters, hemodynamic indicators, lung compliance, lung collapse quality, and postoperative recovery. Key parameters such as airway pressures (peak and plateau), end-tidal carbon dioxide ($EtCO_2$), OI, and FiO_2 were recorded at multiple time points during the surgery and postoperative recovery phase. Recovery metrics such as extubation times, throat pain scores, and hoarseness rates were assessed, as well as the occurrence of complications, including hypoxemia, bronchial blocker-related issues, and pulmonary complications.

2.5. Baseline and preoperative data

Baseline characteristics of the patients were collected through retrospective analysis of electronic medical records. These characteristics included age, gender, body mass index (BMI), smoking history, comorbidities (such as hypertension and diabetes), preoperative pulmonary function (FEV_1), ASA classification, and surgery-related information (type of surgery and operative time). Additionally, postoperative hospital stay duration and complication rates were recorded to ensure comparability between the 2 groups.

2.6. Intraoperative parameters

Intraoperative parameters related to airway management were recorded, including peak airway pressure (Ppeak), plateau airway pressure (Pplat), tidal volume, OI, and end-tidal carbon dioxide partial pressure ($EtCO_2$). These parameters were recorded at the following time points:

P1: 5 minutes after intubation or laryngeal mask airway (LMA) insertion

P2: 10 minutes after the start of OLV

P3: 1 hour after the start of OLV

P4: 10 minutes after the initiation of double-lung ventilation

Additionally, intraoperative lung compliance and the quality of lung collapse on the surgical side were assessed. Lung compliance was calculated based on intraoperative ventilatory mechanics, and the quality of lung collapse was subjectively evaluated by the surgeon using a 3-point scale (1 = poor, 2 = good, 3 = excellent).

2.7. Hemodynamic monitoring

Intraoperative hemodynamic indicators were recorded, including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP). Data were collected at the following 4 time points:

T1: Before anesthesia induction

T2: Immediately after anesthesia induction

T3: 1 minute after airway insertion

T4: 1 minute after airway removal

2.8. Postoperative recovery and complications

Postoperative recovery indicators included extubation time (the time from the end of surgery to successful extubation), throat pain scores (using visual analog scale, 0–10), and the incidence of postoperative hoarseness. Complications were categorized as follows: Perioperative hypoxemia events: Defined as intraoperative $SpO_2 < 90\%$.

Bronchial blocker-related complications: Including airway injury or blocker displacement. Postoperative pulmonary complications: Including pneumonia, atelectasis, or bronchospasm.

2.9. Statistical analysis

All data were analyzed using SPSS 26.0 software. Continuous variables were assessed for normality using the Shapiro–Wilk test. Normally distributed data are presented as mean ± standard deviation (mean ± SD), while non-normally distributed data are presented as median (interquartile range). For between-group comparisons, continuous variables were analyzed using independent samples *t* test or Mann–Whitney *U* test, and categorical variables were analyzed using Chi-square test (χ^2) or Fisher exact test. Intraoperative dynamic data (such as airway pressure, lung compliance, hemodynamic indicators) were analyzed using repeated measures analysis of variance, with post hoc comparisons performed using Bonferroni correction. Postoperative recovery indicators (such as extubation time, throat pain scores) and complication rates were analyzed using *t* test, Mann–Whitney *U* test, and Chi-square test, respectively. Additionally, to reduce the impact of baseline differences, PSM was performed using 1:1 nearest neighbor matching (caliper = 0.2), with matching variables including age, gender, BMI, ASA classification, preoperative pulmonary function, and type of surgery, ensuring baseline balance between the 2 groups after matching. All tests were two-sided, and a *P*-value < .05 was considered statistically significant. When necessary, Bonferroni correction was applied to adjust the significance level.

3. Results

3.1. Baseline characteristics and preoperative factors

After matching, the baseline characteristics of the LMA-BB (experimental) and SLT + BB (control) groups were comparable, Table 1. The average age in both groups was similar, with the LMA-BB group at 55.2 ± 7.5 years and the SLT + BB group at 55.9 ± 7.1 years (*P* = .73). Gender distribution was also balanced, with 21 males and 13 females in the LMA-BB group and 12 males and 22 females in the SLT + BB group (*P* = .84).

Regarding comorbidities, the number of patients with hypertension was 17 in both groups, and those with diabetes were also similar (LMA-BB: 8, SLT + BB: 9), with no significant differences (*P* = 1.00 and *P* = .88, respectively). The BMI was 23.8 ± 3.2 in the LMA-BB group and 24.0 ± 3.3 in the SLT + BB group (*P* = .84), and preoperative pulmonary function (FEV1) was 1.8 ± 0.4 in both groups (*P* = .89).

Surgical parameters, including the type of surgery (lobectomy, segmentectomy, wedge resection), operative time (LMA-BB: 135.0 ± 25.5 minutes, SLT + BB: 135.5 ± 25.6 minutes), and postoperative hospital stay (LMA-BB: 8.4 ± 2.2 days, SLT + BB: 8.5 ± 2.3 days), showed no significant differences (*P* = .94, *P* = .93, and *P* = .94, respectively).

In terms of postoperative complications, the LMA-BB group had 4 complications, while the SLT + BB group had 3, with

Table 1

Baseline characteristics and preoperative factors (pre-matching and post-matching).

Variable	Pre-matching experimental group (n = 36)	Pre-matching control group (n = 57)	Pre-matching statistic value (Z/χ^2)	Pre-matching *P* value	Post-matching experimental group (n = 34)	Post-matching control group (n = 34)	Post-matching statistic value (Z/χ^2)	Post-matching *P* value
Age (years, mean ± SD)	55.2 ± 7.5	56.1 ± 6.9	Z = 0.62	.54	55.2 ± 7.5	55.9 ± 7.1	Z = 0.35	.73
Gender (male/female, n)	22/14	35/22	χ^2=0.18	.7	21/13	12/22	χ^2=0.04	.84
ASA grade (I/II/III, n)	12/16/8	15/30/12	χ^2=0.56	.76	11/15/8	10/17/7	χ^2=0.08	.96
Surgical type (Lobectomy/ Segmentectomy/Wedge resection, n)	15/13/8	22/20/15	χ^2=0.88	.64	14/13/7	13/14/7	χ^2=0.12	.94
Smoking (yes/no, n)	10/26	15/42	χ^2=0.35	.56	10/24	9/25	χ^2=0.05	.83
BMI (mean ± SD)	23.8 ± 3.1	24.2 ± 3.4	Z = 0.54	.59	23.8 ± 3.2	24.0 ± 3.3	Z = 0.21	.84
Preoperative pulmonary function (FEV1, mean ± SD)	1.8 ± 0.4	1.7 ± 0.3	Z = 0.79	.43	1.8 ± 0.4	1.8 ± 0.3	Z = 0.14	.89
Hypertension (yes/no, n)	18/18	28/29	χ^2=0.14	.71	17/17	17/17	χ^2=0.00	1
Diabetes (yes/no, n)	8/28	15/42	χ^2=0.82	.37	8/26	9/25	χ^2=0.02	.88
Operative time (minutes, mean ± SD)	135.2 ± 25.8	137.8 ± 26.4	Z = 0.48	.63	135.0 ± 25.5	135.5 ± 25.6	Z = 0.09	.93
Hospital stay (days, mean ± SD)	8.4 ± 2.1	8.6 ± 2.5	Z = 0.36	.72	8.4 ± 2.2	8.5 ± 2.3	Z = 0.08	.94
Postoperative complications (yes/no, n)	4/32	6/51	χ^2=0.29	.59	4/30	3/31	χ^2=0.09	.92

no significant difference (*P* = .92). These results demonstrate that the matching process successfully minimized differences between the 2 groups.

3.2. Comparison of airway pressure profiles between LMA-BB and SLT + BB groups during thoracic surgery

This study compared airway pressures between the LMA combined with a bronchial blocker (LMA-BB group) and the single-lumen tracheal tube combined with a bronchial blocker (SLT + BB group) during OLV in thoracic surgery, Table 2. The results showed significantly lower peak airway pressure (Ppeak) and plateau airway pressure (Pplat) in the LMA-BB group at all time points (5 minutes after intubation/LMA insertion, 10 minutes after OLV, 1 hour after OLV, and 10 minutes after double-lung ventilation). For example, at 5 minutes after intubation, the Ppeak was 18.2 ± 2.9 cm H_2O in the LMA-BB group compared to 19.5 ± 3.6 cm H_2O in the SLT + BB group (*P* = .01), and the Pplat was 14.4 ± 2.7 cm H_2O in the LMA-BB group versus 15.8 ± 3.4 cm H_2O in the SLT + BB group (*P* = .01). These findings suggest that the LMA-BB group achieved more effective airway management with lower airway pressures throughout the procedure.

3.3. Comparison of ventilation and oxygenation parameters between LMA-BB and SLT + BB groups

The analysis aimed to compare ventilation and oxygenation parameters between the LMA-BB and SLT + BB groups to assess the efficiency of each airway management technique. In addition to lower airway pressures, the LMA-BB group demonstrated better ventilation and oxygenation at multiple time points, Table 3. At 5 minutes after intubation/LMA insertion (P1), the LMA-BB group had significantly lower $EtCO_2$ levels (37.8 ± 4.7 mm Hg vs 39.2 ± 5.1 mm Hg, *P* = .04) and FiO_2 requirements (65 ± 5% vs 67 ± 4%, *P* = .04), with a higher OI (255 ± 22 vs 245 ± 28, *P* = .04). These trends persisted at 10 minutes after OLV (P2), where the LMA-BB group showed lower $EtCO_2$ (36.0 ± 4.2 mm Hg vs 37.5 ± 4.7 mm Hg, *P* = .03) and higher OI (320 ± 30 vs 310 ± 33, *P* = .04). At 1 hour after OLV (P3), the LMA-BB group continued to show lower $EtCO_2$ (36.8 ± 4.1 mm Hg vs 37.9 ± 4.6 mm Hg, *P* = .04) and higher OI (315 ± 34 vs 305 ± 38, *P* = .03). Finally, at 10 minutes after double-lung ventilation (P4), the LMA-BB group maintained better oxygenation with a higher OI (265 ± 30 vs 255 ± 32, *P* = .04) and lower FiO_2 requirements (60 ± 5% vs 62 ± 5%, *P* = .03). These findings confirm that the LMA-BB technique provides superior oxygenation and ventilation management compared to the SLT + BB group.

3.4. Hemodynamic responses during anesthesia and airway management

The LMA-BB group demonstrated more stable hemodynamic responses compared to the SLT + BB group during key procedural phases. Before anesthesia induction (T1), there were no significant differences in HR, SBP, DBP, or MAP between the groups. However, immediately after anesthesia induction (T2), the LMA-BB group had significantly lower HR (73.8 ± 9.7 vs 78.5 ± 10.2 beats/min, *P* = .04), SBP (125.2 ± 10.8 vs 130.3 ± 11.9 mm Hg, *P* = .03), and MAP (92.1 ± 8.2 vs 96.7 ± 8.9 mm Hg, *P* = .04). These differences persisted 1 minute after airway insertion (T3), with the LMA-BB group showing significantly lower HR, SBP, DBP, and MAP (*P* < .05). At 1 minute after airway removal (T4), no significant differences were observed, indicating similar hemodynamic recovery. These findings highlight the advantage of the LMA-BB technique in reducing circulatory stress during anesthesia induction and airway management (Table 4).

3.5. Comparison of intraoperative lung compliance and operative lung collapse quality between LMA-BB and SLT + BB groups

Intraoperative lung function monitoring revealed that the LMA-BB group had significantly better lung compliance and operative lung collapse quality compared to the SLT + BB group. At all measured time points, lung compliance in the LMA-BB group was consistently higher, including 5 minutes after intubation (42.5 ± 6.8 vs 38.7 ± 6.5 mL/cm H_2O, *P* = .018), 10 minutes after OLV (39.8 ± 5.9 vs 36.2 ± 6.1 mL/cm H_2O, *P* = .027), 1 hour after OLV (37.4 ± 6.3 vs 33.5 ± 5.7 mL/cm H_2O, *P* = .012), and 10 minutes after double-lung ventilation (40.2 ± 6.6 vs 36.8 ± 5.9 mL/cm H_2O, *P* = .035). Additionally, the LMA-BB group achieved a significantly higher proportion of "excellent" lung collapse scores (76.5% vs 52.9%, *P* = .032), indicating superior surgical field exposure. These findings suggest that the LMA-BB technique provides better intraoperative lung mechanics and enhances the quality of lung collapse during thoracic surgery (Table 5).

Table 2

Airway pressures (Ppeak and Pplat) at different time points in LMA-BB and SLT + BB groups.

Variable	LMA-BB group (n = 34)	SLT + BB group (n = 34)	Statistic value (Z/χ^2)	*P* value
P1: 5 minutes after intubation/LMA insertion				
Airway pressure (Ppeak, cm H_2O)	18.2 ± 2.9	19.5 ± 3.6	Z = -2.61	.01
Plateau airway pressure (Pplat, cm H_2O)	14.4 ± 2.7	15.8 ± 3.4	Z = -2.73	.01
P2: 10 minutes after single-lung ventilation				
Airway pressure (Ppeak, cm H_2O)	21.5 ± 3.9	22.8 ± 4.2	Z = -2.21	.03
Plateau airway pressure (Pplat, cm H_2O)	17.1 ± 3.1	18.5 ± 3.4	Z = -2.22	.03
P3: 1 hour after single-lung ventilation				
Airway pressure (Ppeak, cm H_2O)	19.8 ± 3.2	20.9 ± 3.6	Z = -2.09	.04
Plateau airway pressure (Pplat, cm H_2O)	16.5 ± 3.0	17.3 ± 3.2	Z = -2.12	.03
P4: 10 minutes after double-lung ventilation				
Airway pressure (Ppeak, cm H_2O)	17.8 ± 3.1	18.7 ± 3.5	Z = -2.05	.04
Plateau airway pressure (Pplat, cm H_2O)	14.2 ± 2.8	15.1 ± 3.0	Z = -2.15	.03

Table 3

Ventilation and oxygenation parameters at different time points in LMA-BB and SLT + BB groups.

Variable	LMA-BB group (n = 34)	SLT + BB group (n = 34)	Statistic value (Z/χ^2)	*P* value
P1: 5 minutes after intubation/LMA insertion				
$EtCO_2$ (mm Hg)	37.8 ± 4.7	39.2 ± 5.1	Z = -2.11	.04
Oxygenation index (OI)	255 ± 22	245 ± 28	Z = 2.08	.04
Tidal volume (TV, mL/kg)	7.4 ± 0.6	7.6 ± 0.7	Z = -1.56	.12
Respiratory rate (RR, breaths/min)	12.1 ± 1.9	12.7 ± 2.2	Z = -2.15	.03
FiO_2 (%)	65 ± 5	67 ± 4	Z = -2.02	.04
P2: 10 minutes after single-lung ventilation				
$EtCO_2$ (mm Hg)	36.0 ± 4.2	37.5 ± 4.7	Z = -2.19	.03
Oxygenation index (OI)	320 ± 30	310 ± 33	Z = 2.04	.04
Tidal volume (TV, mL/kg)	7.8 ± 0.5	7.9 ± 0.6	Z = -1.43	.15
Respiratory rate (RR, breaths/min)	12.5 ± 1.8	12.0 ± 1.7	Z = 1.02	.31
FiO_2 (%)	75 ± 4	76 ± 5	Z = -1.11	.27
P3: 1 hour after single-lung ventilation				
$EtCO_2$ (mm Hg)	36.8 ± 4.1	37.9 ± 4.6	Z = -2.00	.04
Oxygenation index (OI)	315 ± 34	305 ± 38	Z = 2.12	.03
Tidal volume (TV, mL/kg)	7.5 ± 0.6	7.6 ± 0.7	Z = -1.38	.17
Respiratory rate (RR, breaths/min)	12.3 ± 1.9	12.0 ± 1.7	Z = 1.12	.26
FiO_2 (%)	80 ± 4	81 ± 3	Z = -1.01	.31
P4: 10 minutes after double-lung ventilation				
$EtCO_2$ (mm Hg)	37.5 ± 5.0	38.5 ± 5.3	Z = -1.91	.05
Oxygenation index (OI)	265 ± 30	255 ± 32	Z = 2.05	.04
Tidal volume (TV, mL/kg)	7.7 ± 0.6	7.8 ± 0.7	Z = -1.15	.25
Respiratory rate (RR, breaths/min)	12.2 ± 1.6	12.4 ± 1.5	Z = -0.93	.35
FiO_2 (%)	60 ± 5	62 ± 5	Z = -2.22	.03

3.6. Postoperative recovery and complication outcomes between LMA-BB and SLT + BB groups

The comparison of postoperative recovery and complications between the LMA-BB and SLT + BB groups demonstrated significant advantages for the LMA-BB group. The LMA-BB group had a shorter extubation time (12.4 ± 3.2 vs 14.8 ± 3.6 minutes, $P = .003$), lower throat pain scores (2.1 ± 1.0 vs 3.5 ± 1.2, $P < .001$), and a reduced incidence of hoarseness (11.8% vs 29.4%, $P = .043$). Additionally, the LMA-BB group showed fewer perioperative hypoxemia events (5.9% vs 23.5%, $P = .027$), bronchial blocker-related complications (2.9% vs 14.7%, $P = .049$), and postoperative pulmonary complications (8.8% vs 20.6%, $P = .046$). These results indicate that the LMA-BB technique offers superior postoperative recovery and a lower complication rate compared to the SLT + BB technique (Table 6).

4. Discussion

Single-lung ventilation is a critical technique in thoracic surgery for achieving lung collapse on the surgical side, thereby enhancing the surgical field. However, traditional airway management methods, such as the single-lumen tracheal tube combined with a bronchial blocker (SLT + BB), often encounter several challenges in clinical practice. These include improper airway pressure management, hemodynamic fluctuations, and a high incidence of postoperative complications.

This study compared the clinical outcomes of combining a laryngeal mask airway with a bronchial blocker (LMA-BB group) versus using a single-lumen tracheal tube combined with a bronchial blocker (SLT + BB group) in OLV during thoracic surgery. A retrospective analysis of 93 patients was conducted, utilizing PSM to ensure comparability between the 2 groups regarding baseline characteristics and preoperative factors, thereby mitigating the influence of potential confounders on the study results.

One-lung ventilation is a critical technique in thoracic surgery for achieving lung collapse on the surgical side, thereby enhancing the surgical field. However, traditional airway management methods, such as the single-lumen tracheal tube combined with a bronchial blocker (SLT + BB), often encounter several challenges in clinical practice. These include improper airway pressure management, hemodynamic fluctuations, and

Table 4

Comparison of hemodynamic parameters (HR, SBP, DBP, MAP) at different time points between LMA-BB and SLT + BB groups.

Variable	LMA-BB group (n = 34)	SLT + BB group (n = 34)	Statistic value (Z/χ^2)	*P* value
T1: before anesthesia induction				
Heart rate (HR, beats/min)	78.5 ± 10.3	79.2 ± 9.8	Z = -0.42	.67
Systolic blood pressure (SBP, mm Hg)	135.4 ± 12.1	136.8 ± 11.5	Z = -0.52	.6
Diastolic blood pressure (DBP, mm Hg)	81.2 ± 8.7	82.0 ± 9.1	Z = -0.39	.69
Mean arterial pressure (MAP, mm Hg)	99.3 ± 9.0	100.1 ± 9.3	Z = -0.45	.65
T2: immediately after anesthesia induction				
Heart rate (HR, beats/min)	73.8 ± 9.7	78.5 ± 10.2	Z = -2.03	.04
Systolic blood pressure (SBP, mm Hg)	125.2 ± 10.8	130.3 ± 11.9	Z = -2.12	.03
Diastolic blood pressure (DBP, mm Hg)	75.6 ± 7.5	78.9 ± 8.3	Z = -1.92	.05
Mean arterial pressure (MAP, mm Hg)	92.1 ± 8.2	96.7 ± 8.9	Z = -2.05	.04
T3: 1 minute after airway insertion				
Heart rate (HR, beats/min)	75.5 ± 10.1	82.3 ± 9.9	Z = -2.75	.01
Systolic blood pressure (SBP, mm Hg)	128.7 ± 11.5	136.2 ± 12.4	Z = -2.95	.01
Diastolic blood pressure (DBP, mm Hg)	77.3 ± 8.4	81.5 ± 8.9	Z = -2.13	.03
Mean arterial pressure (MAP, mm Hg)	94.5 ± 8.6	99.7 ± 9.0	Z = -2.71	.01
T4: 1 minute after airway removal				
Heart rate (HR, beats/min)	85.2 ± 10.8	88.5 ± 11.4	Z = -1.18	.24
Systolic blood pressure (SBP, mm Hg)	133.4 ± 12.6	137.2 ± 13.1	Z = -1.32	.19
Diastolic blood pressure (DBP, mm Hg)	80.1 ± 8.2	82.7 ± 9.0	Z = -1.21	.23
Mean arterial pressure (MAP, mm Hg)	97.8 ± 9.3	101.5 ± 10.0	Z = -1.47	.14

Table 5

Improved lung compliance and operative lung collapse quality with LMA-BB technique.

Variable	LMA-BB group (n = 34)	SLT + BB group (n = 34)	Statistic value (Z/χ^2)	*P* value
Intraoperative lung compliance (mL/cm H_2O)				
5 minutes after intubation (P1)	42.5 ± 6.8	38.7 ± 6.5	Z = 2.36	.018
10 minutes after single-lung ventilation (P2)	39.8 ± 5.9	36.2 ± 6.1	Z = 2.21	.027
1 hour after single-lung ventilation (P3)	37.4 ± 6.3	33.5 ± 5.7	Z = 2.52	.012
10 minutes after double-lung ventilation (P4)	40.2 ± 6.6	36.8 ± 5.9	Z = 2.11	.035
Quality of operative lung collapse (score)				
Excellent (score = 3), n (%)	26 (76.5%)	18 (52.9%)	χ^2 = 4.62	.032
Good (score = 2), n (%)	7 (20.6%)	12 (35.3%)	χ^2 = 2.18	.14
Poor (score = 1), n (%)	1 (2.9%)	4 (11.8%)	χ^2 = 2.77	.096

Table 6

Comparison of postoperative recovery and complications between LMA-BB and SLT + BB groups.

Variable	LMA-BB group (n = 34)	SLT + BB group (n = 34)	Statistic value (Z/χ^2)	*P* value
Postoperative recovery				
Extubation time (minutes, mean ± SD)	12.4 ± 3.2	14.8 ± 3.6	Z = -3.01	.003
Throat pain (VAS score, mean ± SD)	2.1 ± 1.0	3.5 ± 1.2	Z = -4.05	<.001
Hoarseness (yes/no, n)	4/30	10/24	χ^2 = 4.11	.043
Intraoperative and postoperative complications				
Perioperative hypoxemia (SpO_2 < 90%, yes/no, n)	2/32	8/26	χ^2 = 4.89	.027
Bronchial blocker-related complications (yes/no, n)	1/33	5/29	χ^2 = 3.89	.049
Postoperative pulmonary complications (yes/no, n)	3/31	7/27	χ^2 = 3.98	.046

VAS = visual analog scale.

a high incidence of postoperative complications. With the advancement of minimally invasive surgical techniques, such as video-assisted thoracic surgery, the requirements for airway management tools have become more stringent to ensure the safety and effectiveness of the procedure.

The results demonstrated that the LMA-BB group had significantly lower peak airway pressure (Ppeak) and plateau airway pressure (Pplat) throughout the surgery compared to the SLT + BB group ($P < .05$). This indicates a clear advantage of the LMA-BB technique in managing airway pressures. Lower airway pressures contribute to reducing the risk of lung overdistension and related complications, such as Acute Respiratory Distress Syndrome. These findings are consistent with others, who reported that elevated airway pressures are prone to induce lung overdistension-related lesions.[12–14]

In terms of ventilation and oxygenation parameters, the LMA-BB group consistently outperformed the SLT + BB group at multiple time points, exhibiting lower $EtCO_2$ levels and higher OI, alongside reduced FiO_2 requirements ($P < .05$). This suggests that the LMA-BB technique is more effective in maintaining efficient gas exchange and oxygenation, thereby improving the intraoperative oxygenation status of patients. These observations align with the findings of others, who concluded that LMAs provide more adequate gas exchange and oxygenation compared to tracheal tubes, thereby lowering the incidence of hypercapnia and supporting the results of this study.[15,16]

The LMA-BB group exhibited more stable hemodynamic responses during anesthesia induction and airway insertion, characterized by significantly lower heart rate (HR), SBP, and MAP compared to the SLT + BB group ($P < .05$). Maintaining hemodynamic stability is crucial for minimizing the risk of cardiovascular complications, especially in patients with preexisting hypertension and coronary artery disease. This advantage is corroborated by Hou Tao et al, who demonstrated that the use of LMAs reduces the hemodynamic fluctuations induced by tracheal intubation, highlighting the potential benefits of LMA-based airway management in attenuating the sympathetic response associated with airway manipulation.[17]

Postoperative recovery metrics showed significant advantages for the LMA-BB group, including shorter extubation times, lower throat pain scores, and reduced rates of postoperative complications ($P < .05$). Specifically, patients in the LMA-BB group experienced significantly lower incidences of hoarseness and throat pain, likely attributable to the reduced stimulation of the pharyngeal and airway mucosa during LMA placement compared to tracheal intubation. Additionally, the LMA-BB group had fewer perioperative hypoxemia events, bronchial blocker-related complications, and postoperative pulmonary complications compared to the SLT + BB group, further validating the safety and efficacy of the LMA-BB technique. These results are consistent with the studies by others, which also demonstrated that the combined use of LMAs and bronchial blockers significantly reduces postoperative complications.[18–20]

Although LMA-BB technology shows promise in certain clinical settings, its widespread application is limited by several factors. First, the availability of the necessary equipment may be restricted by hospital resources and budget limitations. Second, the effective use of LMA-BB requires skilled practitioners. Only healthcare providers with appropriate training and experience can ensure the safe and effective use of this technology, potentially limiting its broader implementation. Furthermore, LMA-BB may not be suitable for all patient populations, particularly those with specific airway conditions or other contraindications. Lastly, while LMA-BB has demonstrated advantages in some contexts, clinical practitioners should carefully consider the patient's condition and available resources before deciding whether to adopt this technology, ensuring its optimal use.

Despite the significant clinical implications of this study, there are several limitations. Firstly, it is a single-center retrospective analysis with a relatively small sample size, which may limit the generalizability of the results. Future studies should involve multi-center, large-scale prospective designs to validate these findings across diverse patient populations and clinical settings. Secondly, this study exclusively included patients without chronic obstructive pulmonary disease, and the efficacy and safety of the LMA-BB technique in patients with chronic obstructive pulmonary disease require further investigation. Additionally, future research should explore the specific applications of different types of LMAs in airway management and integrate novel bronchial blocker technologies to further optimize the OLV process and clinical outcomes. Moreover, the SaCo visual LMA utilized in this study demonstrated high operation success rates and low complication rates in clinical practice, but its applicability and long-term effects in various patient groups need more extensive research. Future studies could investigate the use of the SaCo visual LMA in complex airway management scenarios, such as in obese patients, pregnant women, and other special populations, to evaluate its safety and efficacy in different clinical contexts.

5. Conclusion

This study demonstrates that the combination of a LMA-BB offers significant advantages over the traditional single-lumen tracheal tube in OLV during thoracic surgery, including better airway pressure management, improved ventilation and oxygenation, greater hemodynamic stability, and faster postoperative recovery. Based on these findings, the LMA-BB technique is recommended for broader application in thoracic surgery. However, further multi-center, large-scale studies are needed to confirm its efficacy and long-term safety, particularly in specific patient populations, such as the elderly or those with complications, to assess its broader applicability.

Author contributions

Conceptualization: Wanling Wang, Zhenru Zhao, Jiao Guan.
Data curation: Wanling Wang, Yanbin Sun, Jiao Guan.
Formal analysis: Wanling Wang, Yanbin Sun, Zhenru Zhao, Jiao Guan.
Investigation: Wanling Wang, Jiao Guan.
Methodology: Wanling Wang, Jiao Guan.
Validation: Jiao Guan.
Visualization: Yanbin Sun, Zhenru Zhao, Jiao Guan.
Writing – original draft: Wanling Wang, Yanbin Sun, Zhenru Zhao, Jiao Guan.
Writing – review & editing: Wanling Wang, Yanbin Sun, Jiao Guan.

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