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A novel technique of blindly positioning bronchial blockers for one-lung ventilation: a prospective, randomized, crossover study

Seihee Min¹, Susie Yoon², Jiwon Han¹, Jeong-Hwa Seo² and Jae-Hyon Bahk^{2*}

Abstract

Background Several methods for blindly positioning bronchial blockers (BBs) for one-lung ventilation (OLV) have been proposed. However, these methods do not reliably ensure accurate positioning and proper direction. Here, we developed a clinically applicable two-stage maneuver by modifying a previously reported one-stage maneuver for successful insertion of a BB at the appropriate depth and direction in patients requiring lung isolation where a flexible bronchoscope (FOB) is not applicable.

Methods This prospective, randomized, crossover study was conducted at a tertiary university hospital and included 94 patients requiring OLV for elective thoracic surgery under general anesthesia. The patients underwent the one-stage maneuver followed by the two-stage maneuver and vice versa, and the success rates of the two methods were compared. After tracheal intubation, the deflated rigid-angle BB was inserted into the endotracheal tube (ET) until a pre-marked point indicating that the BB was just protruding from the ET tip. To identify the carinal depth without FOB, the BB balloon was inflated and advanced toward the intended side whilst monitoring abrupt changes in peak inspiratory pressure and expiratory tidal volume to indicate placement at the carina. In one-stage maneuver, the BB balloon was deflated and advanced 3 cm further from the estimated carinal depth. During the two-stage maneuver, the same procedure was performed to determine the carinal depth, and the deflated BB was withdrawn and reinserted to a predetermined depth with its tip directed 90 degree toward the target bronchus. The accuracy of BB positioning for both maneuvers was evaluated by a 4-point scale, with grades 1 and 2 considered acceptable for providing OLV.

Results BB placement was more accurate in the two-stage maneuver than in the one-stage maneuver [88.0% (81/92) vs. 73.9% (68/92), relative risk (95% confidence interval [CI]), 0.45 (0.23–0.88), $P < 0.001$]. This improvement was particularly significant when targeting the left main bronchus [84.8% (39/46) vs. 58.7% (27/46), relative risk (95% CI), 0.36 (0.17–0.79), $P < 0.001$].

Conclusions The novel two-stage maneuver significantly improved the success rate of blindly positioning the BB.

Trial registration This study was registered in ClinicalTrials.gov (NCT02981537) on December 05, 2016.

Keywords Airway management, Lung isolation, One-lung ventilation, Bronchial blocker, Thoracic surgery

*Correspondence:

Jae-Hyon Bahk
bahkjh@snu.ac.kr

¹Department of Anesthesiology and Pain Medicine, Chung-Ang University Gwangmyeong Hospital, Chung-Ang University College of

Medicine, 110 Deokan-ro, Gwangmyeong-si, Gyeonggi-do 14353, Republic of Korea

²Department of Anesthesiology and Pain Medicine, Seoul National University Hospital, Seoul National University College of Medicine, 101 Daehak-ro, Jongno-gu, Seoul 03080, Republic of Korea



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Background

Lung isolation and one-lung ventilation (OLV) are indispensable to facilitate thoracic surgery [1–3]. Despite double-lumen tube (DLT) being a conventional device for OLV, a bronchial blocker (BB) is an easily applicable alternative in patients who have limitations of inserting DLTs. Optimal positioning of a BB is critical for providing surgical vision with adequate ventilation. Beyond the conventional lung isolation technique of inserting BBs under fiberoptic bronchoscope (FOB) guidance, there are inevitable clinical scenarios where FOB is unavailable.

Considering these circumstances, several methods have been reported for BB insertion into the target bronchus without an FOB. However, the accuracy and efficacy of these methods appear to be inadequate for clinical use [4–8]. One of the useful methods suggested that capnography changes during inflated BB advancement were practical in predicting carina depth. However, this method was inadequate for correctly placing a BB in the left main bronchus, possibly due to the more acute angle of the left main bronchus [7].

Therefore, we developed a novel two-stage maneuver by modifying the one-stage maneuver described in a previous study [7], to predict appropriate depth of the carina using capnography changes, and then withdraw and reinsert the balloon-deflated BB directed to the intended bronchus, to increase the success rate of blindly positioning BBs. We conducted a crossover study to compare the success rates of the two techniques in the same anatomical structure, so that suggest a novel technique for blindly providing OLV using BBs.

Methods

Ethical approval

This prospective, randomized, crossover study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1509-113-705; Principal Investigator, Jae-Hyon Bahk; 25/08/2016) and registered at ClinicalTrials.gov (NCT02981537, 05/12/2016) prior to patient enrollment. Written informed consent was obtained from all participants. The study was conducted in accordance with the Good Clinical Practice guidelines and the principles of the Declaration of Helsinki. All participants provided written informed consent and could withdraw consent at any time.

Study population and randomization

Patients with American Society of Anesthesiologists (ASA) physical status I–III, aged >18 years, and required OLV for elective thoracic surgery under general anesthesia were enrolled in the study. Patients with tracheostomy, intraluminal lesions in the main bronchus, or severe anatomical distortion and tracheal deviations where BB

insertion could cause bronchial injury were identified in advance through chest CT and excluded from the study. To minimize the risk of bronchial injuries associated with inserting a BB twice through the same endotracheal tube, we measured the tracheal and bronchial diameters to determine patient eligibility. Specifically, tracheal diameters were measured at the midclavicular level, whereas diameters of the left and right main bronchi were measured at 3 mm below the carinal bifurcation where the BB balloon would ultimately be positioned. The study protocol included monitoring and risk mitigation strategies to ensure patient safety.

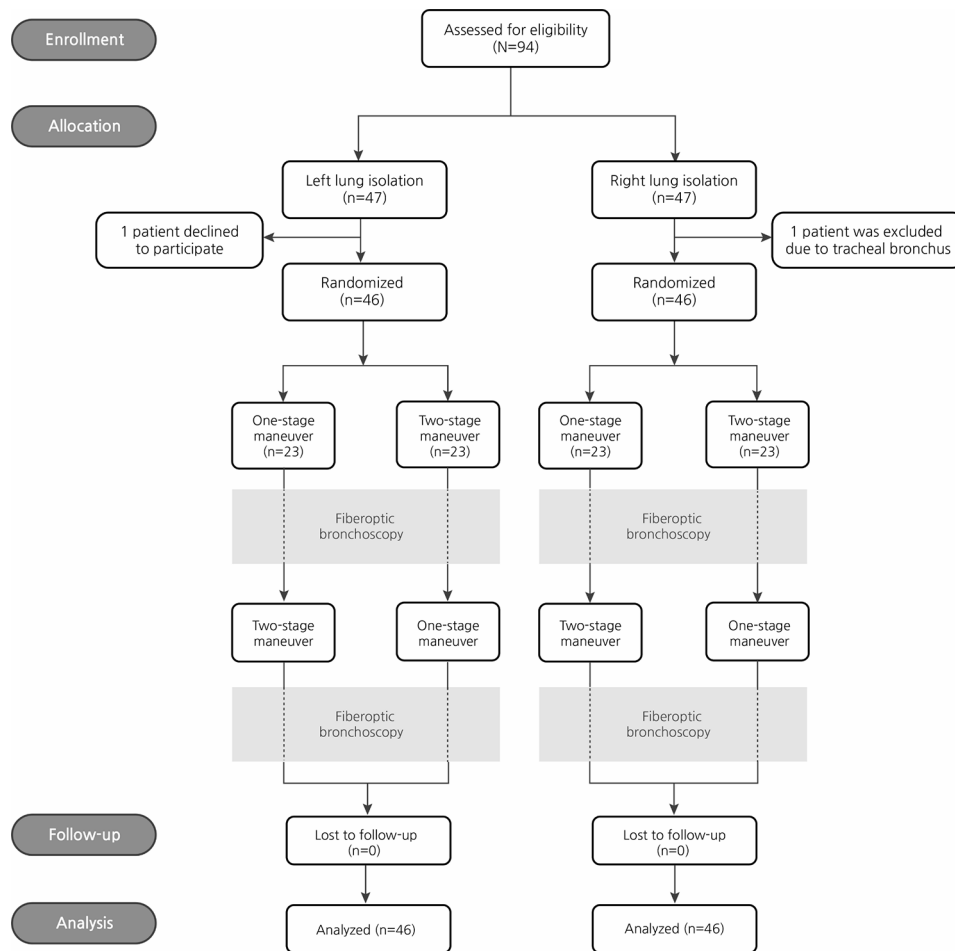
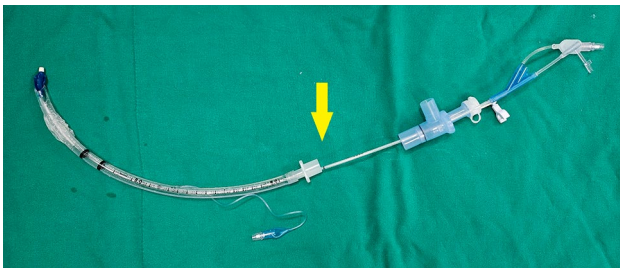
Patients requiring left or right OLV ($n=47$ each) were consecutively recruited and randomly assigned in a 1:1 ratio to undergo either a one-stage maneuver followed by a two-stage maneuver or vice versa as a crossover study. The two techniques were performed on each patient to compare the success rate without anatomical differences. Randomization was conducted by an unrelated assistant using an online program (<http://www.randomization.com>) (Fig. 1). The single investigator who performed the two techniques and another investigator in charge of evaluating and recording the final BB position were not blinded to the group allocation. The patients and researchers who collected other medical records and analyzed the data were blinded to the assignment.

Study protocol

Before inducing general anesthesia, the balloon of a type A Coopdech rigid-angle endobronchial blocker® (Dai-ken Medical Company, Osaka, Japan) was tested with 6 mL of air in water to confirm the absence of air leakage. The balloon was deflated entirely after confirming the absence of air leakage. Subsequently, the BB was inserted into the endotracheal tube through a multiport connector until the BB protruded slightly from the endotracheal tube tip, and the proximal BB point was labeled so that the depth could be used in the study (Fig. 2).

The patients were monitored using electrocardiography, noninvasive arterial blood pressure measurement, pulse oximetry, and bispectral index (BIS) (A-2000 XP; Aspect Medical Systems, Newton, MA, USA). After placing a headrest under the head of the patient, general anesthesia was induced and maintained with intravenous propofol and remifentanyl using a target-controlled infusion pump (Module DPS Orchestra®, Brezins, France). Effect-site concentrations of the drugs were adjusted to 3–5 $\mu\text{g mL}^{-1}$ and 2–6 ng mL^{-1} for propofol and remifentanyl to target BIS of 40–60. Rocuronium of 0.6 mg kg^{-1} was injected for tracheal intubation, and 0.2–0.3 mg kg^{-1} was intermittently administered for muscle relaxation during surgery.

After inducing general anesthesia, the investigator inserted a disposable single-lumen endotracheal tube

**Fig. 1** Consort diagram**Fig. 2** BB preparation wherein the BB protruded from the tip of the endotracheal tube

with an internal diameter of 8.0 mm (Mallinckrodt Medical, Athlone, Ireland) under direct or videolaryngoscopy (UESCOPE; UE Medical Corp., Zhejiang, China) until the distal depth mark of the endotracheal tube passed through the vocal cords. After the intracuff pressure of the endotracheal tube was adjusted to less than 25 cm H₂O (VBM Medizintechnik GmbH, Sulz am Neckar, Germany), volume-controlled mechanical ventilation was started with V_T of 8 mL kg⁻¹ of predicted body weight and an initial respiratory rate of 12 min⁻¹ (Avance; GE

Datex-Ohmeda, Munich, Germany). Before inserting a BB, the balloon was completely deflated, and the surface was lubricated with water-soluble jelly. After removing the headrest to set the cervical spine of the patient in a neutral position, the BB was inserted into the endotracheal tube until the previously labeled point where it protruded from the tip.

To identify carinal depth without FOB, the BB balloon was inflated with 6 mL of air and advanced slowly toward the carina while monitoring for abrupt PIP increases to more than 25 cm H₂O and the expiratory V_T to decrease to a negligible amount (Fig. 3A). Carinal depth was determined immediately after an abrupt PIP decrease and the reappearance of expiratory V_T and EtCO₂ (Fig. 3B).

In the one-stage maneuver, the BB was advanced further by 3 cm after deflating the balloon, directing its tip toward the intended side, as described in a previous study [7]. Subsequently, the BB was reinflated using 4 mL of air for the OLV (Fig. 3C). In the two-stage maneuver, after marking the estimated carinal depth on the BB shaft using the same technique as in the one-stage maneuver, the deflated BB was withdrawn completely from the

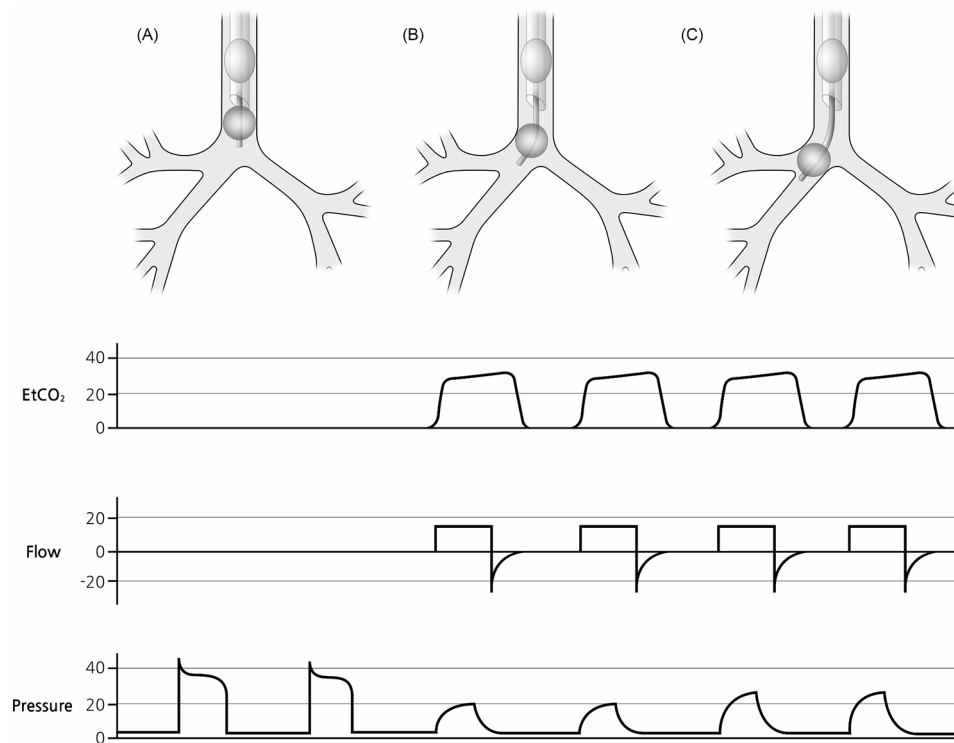


Fig. 3 Changes in EtCO_2 , V_T , and PIP according to BB position. **(A)** When the balloon of the blocker was inflated immediately after protruding from the endotracheal tube tip, EtCO_2 and V_T abruptly decreased, but PIP increased to more than 25 cm H_2O . **(B)** When the inflated balloon of the blocker passed the carina and advanced to a main bronchus, EtCO_2 and V_T reappeared, but PIP decreased. **(C)** The estimated final position of a blindly placed bronchial blocker after 3 cm advancement beyond point B

endotracheal tube and reinserted until the premarked depth + 3 cm with the BB tip 90-degree directed toward the intended side. Subsequently, the BB was reinflated with 4 mL of air for the OLV (Fig. 3C). A single investigator performed both maneuvers according to a standardized protocol.

From BB insertion into the endotracheal tube to placement in the targeted main bronchus, the procedure was completed within 1 min for each technique. The final BB position was evaluated after each technique and recorded with the aid of an FOB (LF-DP; Olympus Optical Co., Tokyo, Japan) by the investigator who was not involved in its positioning. If the BB was misplaced, it was repositioned under FOB guidance. After the correct BB positioning into the mainstem bronchus, the BB was fixed tightly to the endotracheal tube using silk tape to minimize BB movement while changing the position of the patient. During the entire procedure, the patient's lung was ventilated with inspired oxygen fraction of 1.0 and a gas flow rate of 2 L min^{-1} .

After changing the position of the patient from supine to flexed lateral decubitus for thoracic surgery, the final BB position was reassessed using an FOB. During OLV, mechanical ventilation was applied at V_T of 6 mL kg^{-1} of predicted body weight and a PEEP of 5–10 cm H_2O . The inspired oxygen fraction and respiratory rate were

adjusted to oxygen saturation of >95% and end-tidal carbon dioxide in range of 35–45 mm Hg, respectively. After lung resection was completed and the surgeon requested the termination of OLV, the BB was removed from the endotracheal tube. Patients were then transitioned to two-lung ventilation with an FiO_2 of 0.4, V_T of 8 mL kg^{-1} of predicted body weight, and PEEP of 5 cm H_2O . After placing the patients in the supine position and examining any possible mucosal damage of the trachea and both main bronchi using FOB by the investigator, 2–4 mg kg^{-1} of sugammadex was administered to reverse the neuromuscular blockade. After gentle suction of oral secretions, the patient was extubated after recovery of adequate spontaneous breathing and reflexes.

Data collection and study endpoints

Baseline characteristic and comorbidity data of the included patients were collected. The primary outcome was the accuracy of the BB position. We evaluated the BB position on a 4-point scale: Grade 1, when the BB was in the target bronchus with the bronchial cuff just below the tracheal carina (Fig. 4A); Grade 2, when the BB balloon was in the target bronchus with displacement of <5 mm without hindering OLV (Fig. 4B); Grade 3, when the BB was too shallow or too deep to provide OLV (Fig. 4C); and Grade 4, when the BB was not in the target bronchus

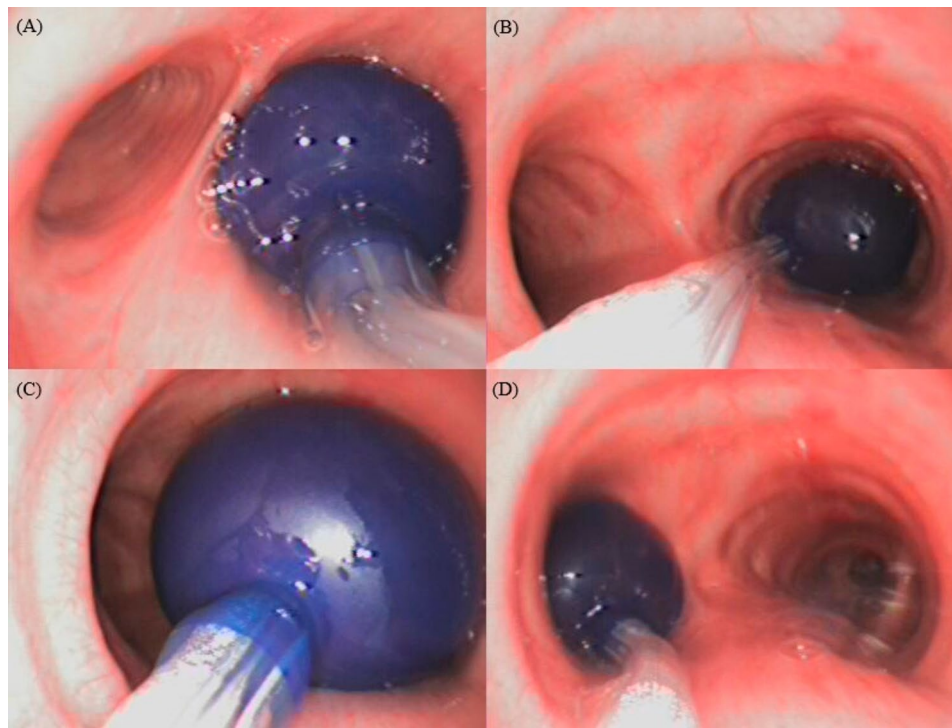


Fig. 4 Evaluating the BB position using a 4-point scale. **(A)** Grade 1: the BB was in the target bronchus with the bronchial cuff just below the tracheal carina **(B)** Grade 2: the BB balloon was in the target bronchus with a displacement < 5 mm without hindering OLV **(C)** Grade 3: the BB was too shallow or too deep to provide OLV **(D)** Grade 4: the BB was not in the target bronchus

(Fig. 4D). Although Grade 1 is ideal for OLV, Grade 2 is considered acceptable.

After BB removal, from the trachea below the endotracheal tube tip to both mainstem bronchi were evaluated whether it is clear, or if there were a few petechiae, coalesced as well as bruised petechiae, or erosions. The time from BB insertion through the endotracheal tube to FOB confirmation was also recorded.

Sample size calculation and statistical analysis

In a previous study [7], 58.9% of BBs were correctly positioned in the left main bronchus for OLV on the third attempt, whereas 85.7% were positioned correctly in the right main bronchus for OLV. Although the depth of placement was accurate in both cases, it showed a significantly lower success rate when targeting the left main bronchus than when targeting the right main bronchus. Therefore, to improve the success rate for directional accuracy by 30% with a type-I error rate of 0.05 and a power of 0.8, the required sample size was calculated to be 42 patients. Considering a 10% dropout rate, we planned to enroll 94 patients.

All data are presented as mean $\pm$ SD or number. Continuous variables were compared using the independent Student's *t*-test after testing for normal distribution using the Kolmogorov-Smirnov test. Categorical variables were compared using Pearson's chi-squared test or Fisher's

exact test. McNemar's test was used to compare the success rate of the one-stage *versus* two-stage maneuvers according to the lung isolation side. A *P* value of <0.05 was considered statistically significant. All statistical analyses were performed using SPSS ver. 21.0 for Windows (SPSS, Chicago, IL, USA).

Results

Among the 94 eligible patients for this study, one declined participation, and one was excluded due to having a tracheal bronchus. No significant differences existed in the clinical characteristics between patients requiring left OLV and those requiring right OLV (Table 1).

Our two-stage maneuver for OLV demonstrated a significantly higher success rate than the one-stage maneuver [88.0% (81/92) vs. 73.9% (68/92), relative risk (95% CI), 0.45 (0.23–0.88), *P*<0.001]. The success rate of the left lung isolation was increased, especially in the two-stage maneuver [84.8% (39/46) vs. 58.7% (27/46), relative risk (95% CI), 0.36 (0.17–0.79), *P*<0.001] (Fig. 5). In other words, among the 19 misplaced cases inserted in the right main bronchus with the one-stage maneuver, 12 were successfully redirected to the left with the two-stage maneuver. Regarding directions that were correctly inserted into the left main bronchus but were not sufficient for OLV (grade 3), prominent differences existed between the two techniques [91.3% (42/46) vs. 60.9%

Table 1 Patient characteristics

	Left lung isolation (n = 46)	Right lung isolation (n = 46)
Age (yr)	58.6 ± 14.8	63.3 ± 11.6
Female	23(50.0%)	19(41.3%)
Height (cm)	161.3 ± 8.8	164.8 ± 9.2
Weight (kg)	61.3 ± 12.0	64.2 ± 11.2
Body mass index (kg/m ²)	23.54 ± 4.05	23.53 ± 3.09
ASA physical status (1/2/3)	9(19.6%) / 36(78.3%) / 1(2.2%)	9(20.0%) / 30(66.7%) / 6(13.3%)
Tracheal diameter (mm)	15.5 ± 2.3	16.2 ± 3.1
Left main bronchus diameter (mm)	11.2 ± 1.6	12.6 ± 1.8
Right main bronchus diameter (mm)	13.3 ± 2.0	15.6 ± 2.6

Data are expressed as mean ± SD or number

(28/46), relative risk (95% CI), 0.22 (0.08–0.60), $P < 0.001$] (Table 2). No significant difference existed in the success rate of the right lung isolation between the two techniques [95.7% (88/92) vs. 94.6% (87/92), $P = 0.999$].

Blindly positioned BB was graded in a 4-point scale: Grade 1 when the BB was in the target bronchus with the bronchial cuff just below the tracheal carina; Grade 2 when the BB balloon was in the target bronchus with displacement of < 5 mm without any possibility of hindering OLV; Grade 3 when the BB was too shallow or too deep to provide OLV; and Grade 4 when the BB was not in the target bronchus.

Regarding directed BBs for left lung isolation, one case was too shallow when using the one-stage maneuver. However, two cases were too shallow, and one was too deep with the two-stage maneuver. In the correctly directed BBs for right lung isolation with both maneuvers, three cases were too deep, and one was too shallow. The only case that was misplaced to the left main bronchus while targeting the right main bronchus with a one-stage maneuver was successfully directed to the right

Table 2 Position of bronchial blockers

	Grade	One-stage maneuver	Two-stage maneuver	P value
Left lung isolation (n = 46)	1	22 (47.8%)	29 (63.0%)	< 0.001
	2	5 (10.9%)	10 (21.7%)	
	3	1 (2.2%)	3 (6.5%)	
	4	18 (39.1%)	4 (8.7%)	
Right lung isolation (n = 46)	1	27 (58.7%)	28 (60.9%)	0.999
	2	14 (30.4%)	14 (30.4%)	
	3	4 (8.7%)	4 (8.7%)	
	4	1 (2.2%)	0 (0.0%)	

using the two-stage maneuver (Table 2). After evaluating the position of BBs, any incorrect positioning was adjusted under FOB before initiating OLV for surgery. As a result, no cases of insufficient lung collapse interfered with surgery or required additional management to achieve adequate OLV.

At the end of the surgery, one developed a few petechiae on the right main bronchus, while two demonstrated some petechiae on the left main bronchus. The time to place the BB in the mainstem bronchus was 4.7 ± 1.6 s longer with the two-stage maneuver than with the one-stage maneuver, which is not clinically important.

Discussion

Although it may not reflect the latest technical advancements of anesthesiology, clinical practice and development based on principles and fundamentals should be continued, considering situations whereby they are inapplicable. From this perspective, this study suggests an efficient method for blindly manipulating BBs without FOB when OLV is inevitable. As BBs are used less frequently than DLTs, the learning curve for their effective use is relatively prolonged. Therefore, researching and

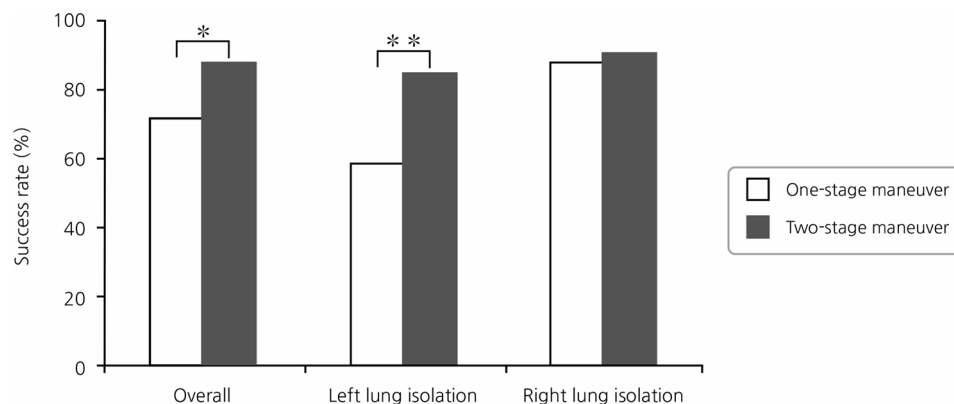


Fig. 5 The success rate of bronchial blocker placement in the target bronchus. * 73.9% (68/92) vs. 88.0% (81/92), relative risk (95% CI), 0.45 (0.23–0.88), $P < 0.001$ compared with the one-stage maneuver. ** 58.7% (27/46) vs. 84.8% (39/46), risk ratio (95% CI), 0.3 (0.1–0.7), $P < 0.001$ compared with the one-stage maneuver

developing clinically applicable methods to shorten this learning period holds significant value [9, 10].

The role of an anesthesiologist in lung isolation and selective ventilation facilitates thoracic surgery [1–3]. Despite DLT being a conventional device to provide lung isolation, BBs are applicable alternatives because of their comparable benefits with designs considering patients for whom DLTs cannot be inserted; therefore, anesthesiologists should be well-trained in using BBs [9, 11–16]. For example, anesthesiologists should be well-trained with BBs for patients having distorted or small airways with limitations in using DLTs for OLV [11, 17–23]. Additionally, 5–8% of patients with primary lung cancer have been reported to have concurrent pharyngeal cancer previously treated with radiation or airway surgery, causing intubation and lung isolation difficulties [24]. Even in patients with tracheostomy, OLV is possible only with BBs [25–28]. Given that patients requiring BBs instead of DLTs often present with anatomical challenges, it is essential to develop methods for blindly achieving the correct direction as well as techniques for accurately determining the appropriate depth during the blind insertion. Inserting a BB too deeply can lead to segmental isolation, obstructing surgical view, and potentially causing injury due to excessive cuff pressure, whereas a shallow insertion can impede patient ventilation. Besides these challenging situations, BBs demonstrate a lower incidence of sore throat/airway injury, provide rapid sequence intubation, and obviate the need to change the endotracheal tube in patients requiring postoperative ventilation, with the comparable efficiency in achieving OLV with DLTs [29–32]. Therefore, we should steer BBs to the target bronchus with or without FOB.

Previous studies on the blind placement of various BBs have demonstrated unsatisfactory results, highlighting the necessity of using FOB guidance for correct BB placement [4–7]. Liang et al. reported successful blind insertion in the left mainstem bronchus with a gum elastic bougie (GEB), a tracheal tube introducer commonly used to guide and insert an endotracheal tube, in combination with the cricoid displacing maneuver [4]. However, this maneuver is only feasible when a GEB is prepared and carries a potential risk of bronchial injury, as the device is relatively rigid. While several methods have been proposed for successful blind BB positioning, most are limited to targeting the left main bronchus. The cricoid displacement maneuver has demonstrated relatively high success rates, but related studies have also been limited to the left main bronchus. The EZ-blocker with a Y-shaped distal end has recently been introduced to facilitate positioning into both left and right mainstem bronchi to provide selective OLV easily [10]. However, this blocker also demonstrated frequent dislocation and required repositioning under FOB guidance, with a higher incidence of

hoarseness compared to DLTs [33–36]. In this aspect, our previous study introduced a one-stage maneuver as a novel method for blindly positioning a BB in both the left and right main bronchi. This approach was easily implementable without requiring additional equipment or changes in patient positioning. Despite achieving comparable accuracy in depth for both bronchi, the study revealed a significantly lower success rate for directional accuracy when targeting the left main bronchus compared to the right one. Specifically, all placements targeting the right mainstem bronchus succeeded on the first attempt, whereas only 66.1% of placements targeting the left mainstem bronchus were successful, even after three attempts [7]. In this respect, our two-stage maneuver offers a novel technique for blind BB positioning, ensuring accurate depth and direction to the target bronchus. Notably, the success rate for the left main bronchus placement improved from 58.9% in prior studies to 84.8% with this method, demonstrating its superior efficacy for achieving reliable OLV compared to previous approaches.

With the one-stage maneuver, the depth of the BB could be determined accurately using PIP and expiratory V_T in most cases; however, 58.9% of the left-targeted BBs were misplaced into the right mainstem bronchus on the first attempt. However, predetermining the depth and inserting the deflated BB in the two-stage procedure significantly reduced misplacement to the opposite bronchus. This increased success rate may be related to the stepwise manipulation of the BB inside the endotracheal tube and trachea. To determine the depth of the BB blindly, we inflated the BB balloon below the endotracheal tube and advanced the BB through the trachea while monitoring PIP and expiratory V_T . However, the balloon-inflated BB inside the trachea might be centralized, easily displacing the BB into the right mainstem bronchus as the bronchus is anatomically wider and more vertical. In the two-stage maneuver, the accurate depth was determined by manipulating the balloon inside the trachea. Subsequently, the insertion side was determined by directing the balloon-deflated BBs to the intended side. By reducing the misplacement to the right with this two-stage maneuver, the final success rate of BB placement in the target bronchus increased. Additionally, the Coopdech rigid-angle blocker has a firm shaft that can be easily steered to the intended side. Therefore, BBs were successfully placed in the target bronchus in our study.

This study had some limitations. First, the success rate of this new technique may be affected by the type of BBs used. Among several types of BBs, we used a recently introduced type A Coopdech rigid-angle endobronchial blocker®, which has a 40° pre-flexed balloon tip with a firm elastic shaft. The previous study, introducing the one-stage maneuver, used the Uniblocker® (Fuji Systems,

Tokyo, Japan), which has a relatively flexible shaft with a distal bend to allow guidance into the targeted bronchus. In that study, the success rate of blind BB placement in the left main bronchus was only 41.1% on the first attempt. However, the same maneuver in the present study demonstrated an increased success rate of 61.7%. Even when using the one-stage maneuver in this crossover study, the increased success rate of targeting the BB to the left mainstem bronchus may have been attributed to the type of BB used. Therefore, it is helpful to choose a BB with a firm shaft and tip bent up when blindly inserting it.

Second, since we evaluated bronchial injury only after removing BBs at the end of the surgery, and because of the crossover study design, we could not compare the mucosal damage between the maneuvers. However, we demonstrated a low bronchial injury incidence, which might be related to a previous report that the incidence of having a sore throat was lower with Coopdech endobronchial blockers than with Arndt or Univent blockers. Post-operatively, no patient required further laryngoscopic evaluation or management because of voice quality changes, sore throat, or bronchial mucosal hemorrhage.

Third, a single expert anesthesiologist performed both techniques in this study. Considering that BBs are not used as frequently as DLT in clinical practice, the results of blindly positioning BBs could be influenced by the anesthesiologist's level of experience. To address this, we designed the study as a crossover study to eliminate the potential differences caused by the anesthesiologist's experience and the patient's anatomical variations. This approach allowed for a straightforward comparison of the two techniques. The goal of this study was to introduce a novel method that is not only easier to implement but also has a higher success rate, making it a practical option in clinically necessary situations.

Conclusions

We successfully developed a clinically applicable two-stage maneuver by modifying a previously reported one-stage maneuver. Using this maneuver, the success rate of blindly positioning BB to the target bronchus can be significantly increased when OLV is required without FOB assistance. This technique is a safe and efficient maneuver that can be easily practiced; therefore, it is helpful for lung isolation in patients with limitations using DLTs in situations where an FOB is unavailable.

Abbreviations

OLV	One-Lung Ventilation
DLT	Double-Lumen Tube
BB	Bronchial Blocker
FOB	Fiberoptic Bronchoscope
ASA	American Society of Anesthesiologists
BIS	Bispectral Index
GEB	Gum Elastic Bougie

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None.

Author contributions

S.M: Conceptualization, Methodology, Investigation, Data Curation, Writing – Original Draft, Writing – Review and Editing. S.Y: Conceptualization, Methodology, Investigation. J.H: Data Curation, Writing – Review and Editing. J-H.S: Conceptualization, Methodology, Data Curation, Writing – Review and Editing. J-H.B: Conceptualization, Methodology, Writing – Review and Editing.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

This prospective, randomized, crossover study was approved by the Institutional Review Board of Seoul National University Hospital (IRB No. 1509-113-705; Principal Investigator, Jae-Hyon Bahk; 25/08/2016) and registered at ClinicalTrials.gov (NCT02981537, 05/12/2016) prior to patient enrollment. Written informed consent was obtained from all participants. The study was conducted in accordance with the Good Clinical Practice guidelines and the principles of the Declaration of Helsinki. All participants provided written informed consent and could withdraw consent at any time.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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