



DEPARTMENT OF ANESTHESIOLOGY

JOURNAL CLUB

**Tuesday June 28, 2016
1800 HOURS**

**LOCATION:
Pan Chanco Private Dining Room
44 Princess Street**



**PRESENTING ARTICLES:
Dr. Ian Gilron & Dr. Jamei Eng**

Sponsored by: Merck – Mr. Dan McIsaac

SUGGESTED GUIDELINES FOR CRITICAL APPRAISAL OF PAPERS
ANESTHESIOLOGY JOURNAL CLUB
QUEEN'S UNIVERSITY
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Two presenters will be assigned to choose and present summaries of their papers. Ideally the two papers will represent similar topics but contrasting research methodologies. The focus remains on critical appraisal of the research and manuscript, more than on the actual contents of the article. Each presenter will then lead an open discussion about the article, based around the guidelines below. The object is to open up the appraisal to wide discussion involving all participants.

GENERAL

1. Title of paper: Does it seem like an important problem? Does it reflect the purpose/results?
2. Authors, institution and country of origin

INTRODUCTION

1. What is the problem being addressed?
2. What is the current state of knowledge of the problem studied?
3. What is the hypothesis being tested?
4. How does testing the hypothesis help solve the stated problem?

METHODOLOGY

1. Study design:
 - a) Clinical trial vs. systematic review/meta-analysis
 - b) Prospective vs. retrospective
 - c) Observational vs. Experimental
 - d) Randomized or not
 - e) Blinded or not
2. Population studied:
 - a) Human, animal, other
 - b) Justification
 - c) Control groups: experimental vs. historical
 - d) Is the sample size/power calculated, and how?
 - e) Is the population similar to your own practice?
 - f) Single vs. multi-centre
3. Is the study ethically sound?
 - a) Clinical equipoise
 - b) Does treatment meet standard of care (esp controls)?
 - c) Appropriate consent and institutional ethics approval
4. Exclusions: what groups are excluded and why?
5. Experimental protocol
 - a) Is it designed to test the hypothesis?

- b) Is it detailed enough to be reproducible?
 - c) Is the methodology validated?
 - d) Are the drugs/equipment used detailed?
 - e) How does the randomization take place?
- 6. What are the primary endpoints?
- 7. Is power sufficient to justify secondary endpoints?
- 8. Is the protocol clinically relevant?
- 9. Data collection and analysis
- 10. Statistical analysis: Is it appropriate? Are results

RESULTS

- 1. Are the groups comparable?
- 2. Were any subjects/data eliminated?
- 3. Analyzed by intent to treat?
- 4. Are adequate details of results provided? - data, graphs, tables

DISCUSSION

- 1. What is the main conclusion of the study?
- 2. Do the results support this conclusion?
- 3. Do the results address the stated purpose/hypothesis of the study?
- 4. How do the authors explain the results obtained?
- 5. Are there any alternative interpretations to the data?
- 6. Are the results clinically as well statistically relevant?
- 7. How do the results compare with those of previous studies?
- 8. What do the results add to the existing literature?
- 9. What are the limitations of the methods or analysis used?
- 10. What are the unanswered questions for future work?

APPLICABILITY OF THE PAPER

- 1. Have you learned something important from reading this paper?
- 2. Will the results of this study alter your clinical practice?



Bronchial blocker versus left double-lumen endotracheal tube in video-assisted thoracoscopic surgery: a randomized-controlled trial examining time and quality of lung deflation

Comparaison du bloqueur bronchique à la sonde endotrachéale à double lumière gauche en chirurgie thoracoscopique vidéoassistée: une étude randomisée contrôlée examinant le temps et la qualité de l'affaissement du poumon

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Abstract

Introduction Double-lumen endotracheal tubes (DL-ETT) and bronchial blockers (BB) have both been used for lung isolation in video-assisted thoracic surgery (VATS). Though not well studied, it is widely thought that a DL-ETT provides faster and better quality lung collapse. The aim of this study was to compare a BB technique vs a left-sided DL-ETT strategy with regard to the time and quality

of lung collapse during one-lung ventilation (OLV) for elective VATS.

Methods Forty patients requiring OLV for VATS were randomized to receive a BB ($n = 20$) or a left-sided DL-ETT ($n = 20$). The primary endpoint was the time from pleural opening (performed by the surgeon) until complete lung collapse. The time was evaluated offline by reviewing video recorded during the VATS. The quality of lung deflation was also graded offline using a visual scale (1 = no lung collapse; 2 = partial lung collapse; and 3 = total lung collapse) and was recorded at several time points after pleural incision. The surgeon also graded the time to complete lung collapse and quality of lung deflation during the procedure. The surgeon's guess as to which device was used for lung isolation was also recorded.

Results Of the 40 patients enrolled in the study, 20 patients in the DL-ETT group and 18 in the BB group were analyzed. There mean (standard deviation) time to complete lung collapse of the operative lung was significantly faster using the BB compared with using the DL-ETT [7.5 (3.8) min vs 36.6 (29.1) min, respectively; mean difference, 29.1 min; 95% confidence interval, 1.8 to 7.2; $P < 0.001$]. Overall, a higher proportion of patients in the BB group than in the DL-ETT group achieved a quality of lung collapse score of 3 at five minutes (57% vs 6%, respectively; $P < 0.004$), ten minutes (73% vs 14%, respectively; $P = 0.005$), and 20 min (100% vs 25%, respectively; $P = 0.002$) after opening the pleura. The surgeon incorrectly guessed the type of device used in 78% of the BB group and 50% of the DL-ETT group ($P = 0.10$).

This article is accompanied by an editorial. Please see Can J Anesth 2016; 63: this issue.

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Conclusion *The time and quality of lung collapse during OLV for VATS was significantly better when using a BB than when using a left-sided DL-ETT. Surgeons could not reliably determine which device was being used based on the time and quality of lung collapse. This trial was registered at ClinicalTrials.gov number, NCT01615263.*

R sum 

Introduction *Les sondes endotrach ales   double lumi re (SET-DL) et les bloqueurs bronchiques (BB) ont tous deux  t  utilis s pour isoler un poumon pendant une chirurgie thoracique vid o-assist e (CTVA). Bien que peu  tudi , on pense commun ment qu'une SET-DL procure un affaissement du poumon plus rapide et de meilleure qualit . L'objectif de cette  tude  tait de comparer une technique avec BB   une strat gie de SET-DL du c t  gauche en ce qui touche le temps et la qualit  de l'affaissement pulmonaire pendant une ventilation unipulmonaire (VUP) pour une CTVA  lective.*

M thode *Quarante patients n cessitant une VUP pour une CTVA ont  t  randomis s   recevoir un BB (n = 20) ou une SET-DL du c t  gauche (n = 20). Le crit re d' valuation principal  tait le temps entre l'ouverture pleurale (r alis e par le chirurgien) et le d gonflement complet du poumon. Cet intervalle a  t   valu  hors ligne en passant en revue les enregistrements vid o r alis s pendant la CTVA. La qualit  du d gonflement du poumon a  galement  t  not e hors ligne   l'aide d'une  chelle visuelle (1 = aucun d gonflement du poumon; 2 = d gonflement partiel du poumon; et 3 = d gonflement complet du poumon) et a  t  enregistr e   diff rents moments dans le temps apr s l'incision pleurale. Le chirurgien a  galement not  le temps n cessaire   d gonfler le poumon et la qualit  de d gonflement du poumon pendant l'intervention. La supposition du chirurgien quant au dispositif utilis  pour l'isolation du poumon a  galement  t  enregistr e.*

R sultats *Parmi les 40 patients inscrits   l' tude, 20 patients du groupe SET-DL et 18 du groupe BB ont  t  analys s. Le temps moyen ( cart type) jusqu'au d gonflement complet du poumon op r   tait significativement plus rapide dans le groupe BB par rapport au groupe SET-DL [7,5 (3,8) min vs 36,6 (29,1) min, respectivement; diff rence moyenne, 29,1 min; intervalle de confiance 95 %, 1,8   7,2; P < 0,001]. Globalement, une plus importante proportion de patients du groupe BB que du groupe SET-DL est parvenue   un score de 3   cinq minutes (57 % vs 6 %, respectivement; P < 0,004), dix minutes (73 % vs 14 %, respectivement; P = 0,005), et 20 min (100 % vs 25 %, respectivement; P = 0,002) en mati re de qualit  du d gonflement du poumon apr s l'ouverture de la pl vre. La supposition du chirurgien sur le type de dispositif  tait erron e dans 78 % des cas*

dans le groupe BB et 50 % des patients du groupe SET-DL (P = 0,10).

Conclusion *Le temps n cessaire jusqu'au d gonflement du poumon et la qualit  du d gonflement pendant une VUP pour une CTVA  taient significativement meilleurs en utilisant un BB qu'en utilisant une SET-DL du c t  gauche. Les chirurgiens n'ont pas pu d terminer de fa on fiable quel dispositif  tait utilis  en se fondant sur le temps et la qualit  du d gonflement du poumon. Cette  tude a  t  enregistr e au ClinicalTrials.gov, num ro NCT01615263.*

Video-assisted thoracoscopic surgery (VATS) is a technique increasingly used in thoracic surgery.¹ A key to successful VATS surgery is maximizing intrathoracic visualization by optimizing the quality of lung isolation and deflation within the relatively closed thoracic cavity. Double-lumen endotracheal tubes (DL-ETT) have generally been considered the gold standard for lung isolation and are considered by many to offer more rapid and better quality lung collapse when compared with bronchial blockers (BB).^{2,3} Nevertheless, previous studies comparing lung deflation using either a DL-ETT or BB have provided conflicting results.⁴⁻¹³ Moreover, the majority of these studies had significant limitations. For example, some studies included open thoracotomies along with VATS; other studies used subjective and not standardized criteria to evaluate the quality of lung collapse, and few studies reported time to "complete" lung collapse.^{4,6} Furthermore, the efficacy of BB for lung deflation might be manufacturer/model specific as their internal BB channels, which allow for the egress of air, have different diameters.^{8,11}

A recent systematic review and meta-analysis comparing the efficacy and adverse effects of DL-ETTs vs BBs identified 22 papers on the subject, though only nine papers with relevant data were analyzed.¹⁴ The authors found no significant differences between DL-ETTs and BBs in the time to lung collapse or in the quality of lung deflation; however, the vast majority of these studies were in thoracotomy patients. During conventional thoracotomy, it is easy for the surgeon to compensate for a non-optimal lung deflation by using a lung retractor or direct lung manual compression. In contrast, during VATS it is more difficult for the surgeon to deal with a non-optimal lung deflation. Thus, a thoracic surgeon could qualify lung deflation during thoracotomy as "acceptable", although the same degree of lung deflation in VATS would be considered "unacceptable". This highlights why the quality of lung deflation is of particular importance during VATS.

In our own experience, we have found the use of BB to offer a similar or even better lung collapse than left-sided DL-ETT during VATS, particularly when a brief period of apnea is used just prior to initiating lung isolation. Despite this, the question whether BBs are similar to DL-ETTs, especially for VATS, is uncertain and has frequently been the source of considerable discussion between anesthesiologists and thoracic surgeons. Accordingly, the purpose of this study was to compare the efficacy of a BB when optimally used (i.e., with periods of apnea just prior to lung isolation and just after pleural opening) with that of a left-sided DL-ETT with respect to the time and quality of lung collapse during VATS.

Methods

This study protocol was approved (April 2012) by our local Research Ethics Board (Comité d'éthique à la recherche de l'Institut universitaire de cardiologie et de pneumologie de Québec - Université Laval). This was a prospective randomized single-blinded (i.e., only the patients and the thoracic surgeons were blinded to the group assignment) controlled study in patients requiring one-lung ventilation (OLV) for VATS. Written informed consent was obtained from consecutively scheduled adult patients undergoing OLV for elective left or right VATS. Exclusion criteria included patients with previous or anticipated difficult intubation, prior chemotherapy or thoracic radiotherapy, severe chronic obstructive pulmonary disease or asthma (forced expiratory volume in one second < 50% predicted), and pleural and/or interstitial pathology. There were some *a priori* post-randomization exclusions, including bronchoscopic findings precluding the use of the specific randomized devices (e.g., origin of the right upper lobe (RUL) bronchus is too close to the carina, precluding use of the BB) and severe oxygen desaturation occurring at any time during the observation period (i.e., until complete lung collapse was achieved) necessitating ventilation of the non-dependent lung.

Before anesthesia induction, patients were assigned by computer-generated randomization to one of two study groups, left-sided DL-ETT (Mallinckrodt™ left endobronchial tube; Mallinckrodt Medical, Cornamaddy, Athlone, Westmeath, Ireland) or BB (Fuji Uniblocker; Fuji Systems, Tokyo, Japan) with the internal channel intentionally occluded to exclude any passive contribution to lung collapse. Just prior to anesthesia induction -and after the anesthesiologist confirmed the absence of a potentially difficult airway- research staff opened a sealed envelope indicating the device to be used. Thoracic surgeons were blinded to group assignment throughout the procedure.

Anesthesia management included application of standard monitoring¹⁵ and a standardized intravenous induction of anesthesia with propofol and sufentanil, with muscle relaxation (rocuronium) used according to local practice. Anesthesia was maintained with an inhaled anesthetic (sevoflurane or desflurane). For patients with a baseline heart rate < 100 beats·min⁻¹, intravenous glycopyrrolate 0.2 mg was administered prior to induction to reduce the production of tracheobronchial secretions.

Lung isolation methods

After induction of anesthesia, the patient's trachea was intubated with either a single-lumen 8.0-mm internal diameter endotracheal tube (SL-ETT) for the BB group or a left-sided DL-ETT (37 Fr for females, 39 Fr for males). All BBs were placed via the SL-ETT using a flexible bronchoscope (FOB). Bronchial blockers were positioned distally in the main bronchus with their cuff deflated. Left-sided DL-ETTs were positioned with the FOB at an appropriate depth to allow positioning the tracheal carina between the radiopaque black line of the endobronchial aspect of the DL-ETT and the upper part of the blue bronchial cuff.¹⁶ An attending anesthesiologist or a resident directly supervised by an attending anesthesiologist (who confirmed all device placements) placed the devices for both the BB group and the left-sided DL-ETT group.

Prior to OLV, mechanical ventilation operated in a volume-controlled mode with a tidal volume of 8-10 mL·kg⁻¹ (ideal body weight), respiratory rate of 10 breaths·min⁻¹, positive end-expiratory pressure (PEEP) of 5 cm H₂O, and F_iO₂ of 1.0. After the patients were positioned in a lateral decubitus position, the BB cuff or DL-ETT bronchial cuff was inflated under FOB guidance, and OLV was initiated using volume-controlled ventilation (tidal volume of 5-7 mL·kg⁻¹ ideal body weight with a respiratory rate of 14-16 breaths·min⁻¹, PEEP of 5 cm H₂O, and F_iO₂ of 1.0). The internal channel of the BB was deliberately occluded. After the pleura had been open for 20 min, the F_iO₂ was adjusted to maintain O₂ saturation > 95%.

In the left-sided DL-ETT group, lung isolation was initiated by clamping the bronchial or tracheal lumen of the Y-connector (corresponding to the lung to be isolated) and opening the corresponding lumen of the DL-ETT to allow for passive lung deflation. Just before inflating the BB balloon in the BB group, a 30-sec apnea period was instituted immediately prior to initiating OLV. A second 30-sec apnea period, also with the BB balloon transiently deflated, was initiated at the time of the pleural incision. In the left-sided DL-ETT group, a "sham" apnea period was performed at the beginning of OLV to ensure study

blinding of the thoracic surgeon. For the sham apnea period in the DL-ETT group, the anesthesiologist made similar gestures as in the BB group but without opening the airway or stopping the ventilation. A second ‘‘sham’’ apnea period was also conducted in the DL-ETT group at the time of pleural incision.

Surgeons were absent from the operating room during DL-ETT or BB placement and blinded to the airway device by means of a drape placed over the lung isolation device and the endotracheal tube. The FOB video monitor was oriented such that the surgical team could not identify the lung isolation device being used.

To assess the time of lung collapse and objectively evaluate the quality of lung deflation, we established a scoring system generally based on previously published studies.^{4–8} Fig. 1 outlines the standardized definition of lung collapse on a three-point visual and descriptive scale, where 1 = no lung collapse; 2 = partial lung collapse; and 3 = total lung collapse. The thoracic surgeons and the three observers performing the offline video examinations of lung deflation also used this three-point scale.

The primary endpoint was the time from when the surgeon opened the pleura until complete lung collapse (i.e., score of 3 on the three-point scale) as determined from the offline analysis of video recordings taken during the procedure. For the video analysis, a DVD recorder (Sony RDRHX730, Sony Corporation, Malaysia) linked to the surgical camera (Olympus CV-180, Olympus Canada Inc., Richmond Hill, ON, Canada) was used to record the entire

duration of surgery. The VOB files obtained were converted to WMV files and edited with Windows Movie Maker (Microsoft Corporation; Microsoft Canada Headquarters, Mississauga, ON, Canada). This allowed the three observers blinded to group assignment (i.e., two thoracic surgeons and one cardiothoracic anesthesia fellow) to analyze the video examination data offline (i.e., 30-sec clips edited every five minutes from the videos recorded during VATS). The video clips reviewed were mixed from random group and time sequences and scored using the same standardized three-point scale as previously described. Several secondary endpoints were also recorded. The offline quality of lung deflation was evaluated at standardized time points -i.e., immediately on pleural opening (0 min) and five, ten, and 20 min after pleural opening, using the same visual and chart scale as for the primary endpoint.

In addition to performing the offline assessments, the thoracic surgeons conducted a clinical evaluation of the time to achieve complete lung collapse and the quality of lung deflation using the same scale as for the offline evaluation. Other secondary endpoints included having the surgeon guess the type of device being used. This was done 20 min after pleural opening and before any exploration of the hilum. The use of any suction to assist lung collapse was also recorded.

Statistical analysis

All data were analyzed using the statistical package program SAS® 9.3 (SAS Institute Inc., Cary, NC, USA).

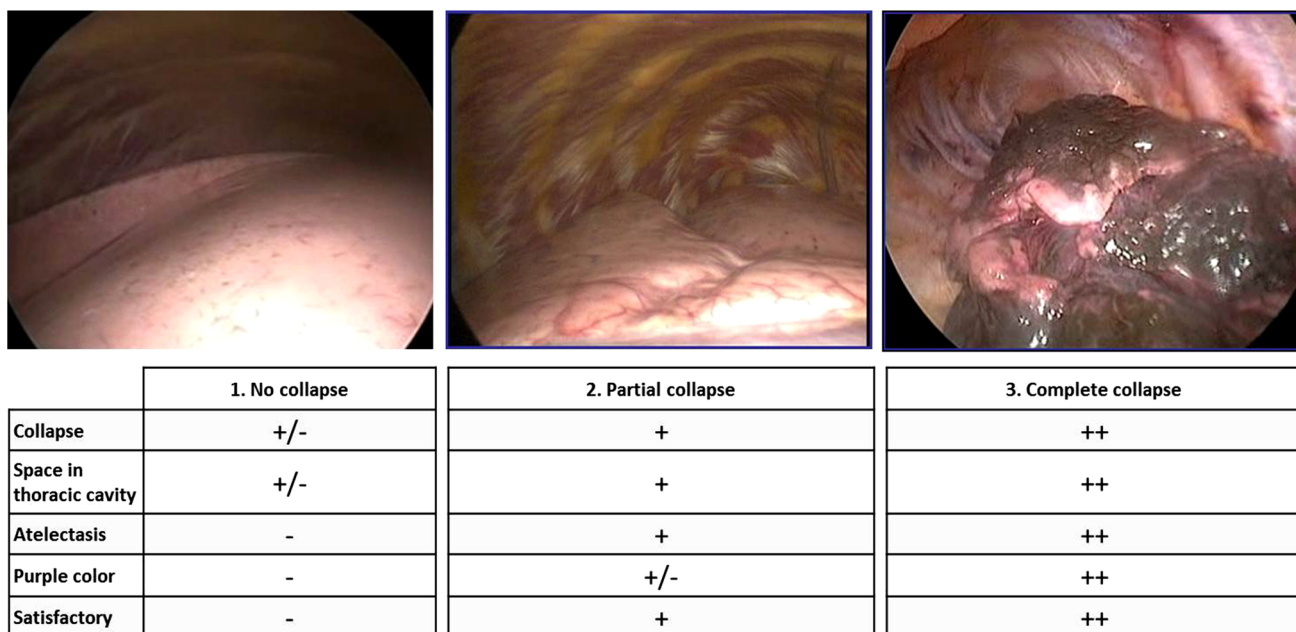


Fig. 1 Lung collapse scoring system incorporating both visual and descriptive features. A score of 1 = no collapse; a score of 2 = partial collapse; a score of 3 = complete lung collapse. Although scores of 2

and 3 were considered to indicate satisfactory surgical conditions, the primary study endpoint targeted a score of 3

Our sample size estimate was based on the time to complete lung collapse evaluated by video examination (i.e., our primary endpoint). We used data from Campos *et al.*⁶ where they reported a mean (standard deviation [SD]) collapse time of 18 (7.2) min after initiation of OLV in the DL-ETT group. Assuming a 40% difference between groups with an alpha of 0.05 and a power of 0.80, we estimated that we would require a sample size of 18 patients per group. We randomized 40 patients (20 subjects per group) to account for potential post-randomization exclusions.

Clinical observation data were log-transformed prior to undergoing analysis of variance (ANOVA). Statistical results from these parameters were expressed with transformed values. Tukey's multiple comparison technique was applied *post hoc* to the ANOVA to compare pairs of group means. The univariate normality assumption was verified using the graphical representations and the Shapiro-Wilk test. The Brown-Forsythe variation of Levene's test statistic was used to verify the homogeneity of variances. The data regarding time to lung collapse were analyzed using a mixed model with heterogeneous variances for the two techniques. Quality of lung collapse was analyzed with Fisher's exact test. All reported *P* values are two sided. As the secondary outcome of quality of lung collapse was evaluated at four different times (0, 5, 10, and 20 min after lung isolation), a Bonferroni correction was applied and $P < 0.0125$ was considered significant.

Video examination data were also secondarily analyzed using a model based on the probability of observing a given lung deflation score at a given time. From the model, the parameter $T_{50,3}$ (time associated with 50% probability of observing a complete lung collapse score of 3) was estimated using the solver function in Microsoft Excel. The Appendix includes a description and analysis of the model. The magnitude of interobserver agreement regarding the video examination data was determined using a weighted Kappa statistic where 0-0.20 would denote slight agreement; 0.21-0.40, fair agreement; 0.41-0.60, moderate agreement; 0.61-0.80, substantial agreement, and > 0.81 almost perfect agreement.¹⁷

Results

Eighty-eight patients undergoing elective lung resection by VATS were screened during a five-month period. Forty-eight patients met exclusion criteria and 40 patients were subsequently randomized, 20 in each group (Fig. 2). Two patients were excluded after randomization, both within the BB group. The first patient was excluded due to an anatomic variation of the RUL bronchus precluding use of

a BB. The second patient was excluded after experiencing a severe episode of arterial oxygen desaturation that happened shortly after initiating OLV. This episode necessitated ventilation of the non-dependent lung. Both groups were similar in terms of their demographic variables (Table 1), and there was no difference between groups regarding left- or right-sided surgery.

The remaining results are presented in two parts, the first part is the *video examination data* (i.e., primary outcome) obtained from the offline review of the video clips edited from the video recorded during the VATS procedures. Due to technical problems, recordings from eight patients (four in each group) are not available. The level of agreement between the three observers of video clip examinations showed substantial interobserver agreement (kappa = 0.68). The second part is the *clinical observation data* obtained during surgery (Fig. 2).

Results for the primary endpoint of this study are summarized in Table 2. The video review time intervals from pleural opening until complete lung collapse showed a significantly faster mean (SD) time to complete collapse of the operative lung using the BB compared with using the DL-ETT [7.5 (3.8) min vs 36.6 (29.1) min, respectively; mean difference, 29.1 min; 95% confidence interval (CI), 1.8 to 7.2; $P < 0.001$].

In the video examination data (Table 3), a higher proportion of patients in the BB group achieved a quality of lung collapse score of 3 after pleural opening when compared with the DL-ETT group at five minutes (57% vs 6%, respectively; $P = 0.004$), ten minutes (73% vs 14%, respectively; $P = 0.005$), and 20 min (100% vs 25%, respectively; $P < 0.001$).

In the clinical observation data, the mean (SD) time from pleural opening until complete lung collapse was faster using the BB than using the DL-ETT [10.3 (10.6) min vs 22.9 (21.4) min, respectively; mean difference, 12.5 min; 95% CI, 1.1 to 3.8; $P = 0.05$]. We observed better quality lung deflation (Table 4) in favour of the BB group following pleural opening at five, ten, and 20 min. At 20 min, the thoracic surgeons verified total lung collapse in 78% of the BB group vs 45% of the DL-ETT group ($P = 0.05$). The mean (SD) interval from beginning OLV until pleural opening was not different between the DL-ETT and BB groups [18.0 (6.8) min vs 22.3 (6.2) min, respectively; $P = 0.15$].

The surgeons' guesses regarding the type of lung isolation device were correct in only four of 18 (22%) patients in the BB group and ten of 20 (50%) patients in the left-sided DL-ETT group (effect size difference, 28%; 95% CI, -8 to 54; $P = 0.10$). Combining all groups, the surgeons' guesses were correct in only 14 of 38 (37%) cases. Rescue suction was used only once in the BB group and not used at all in the left-sided DL-ETT group ($P = 0.47$). There was

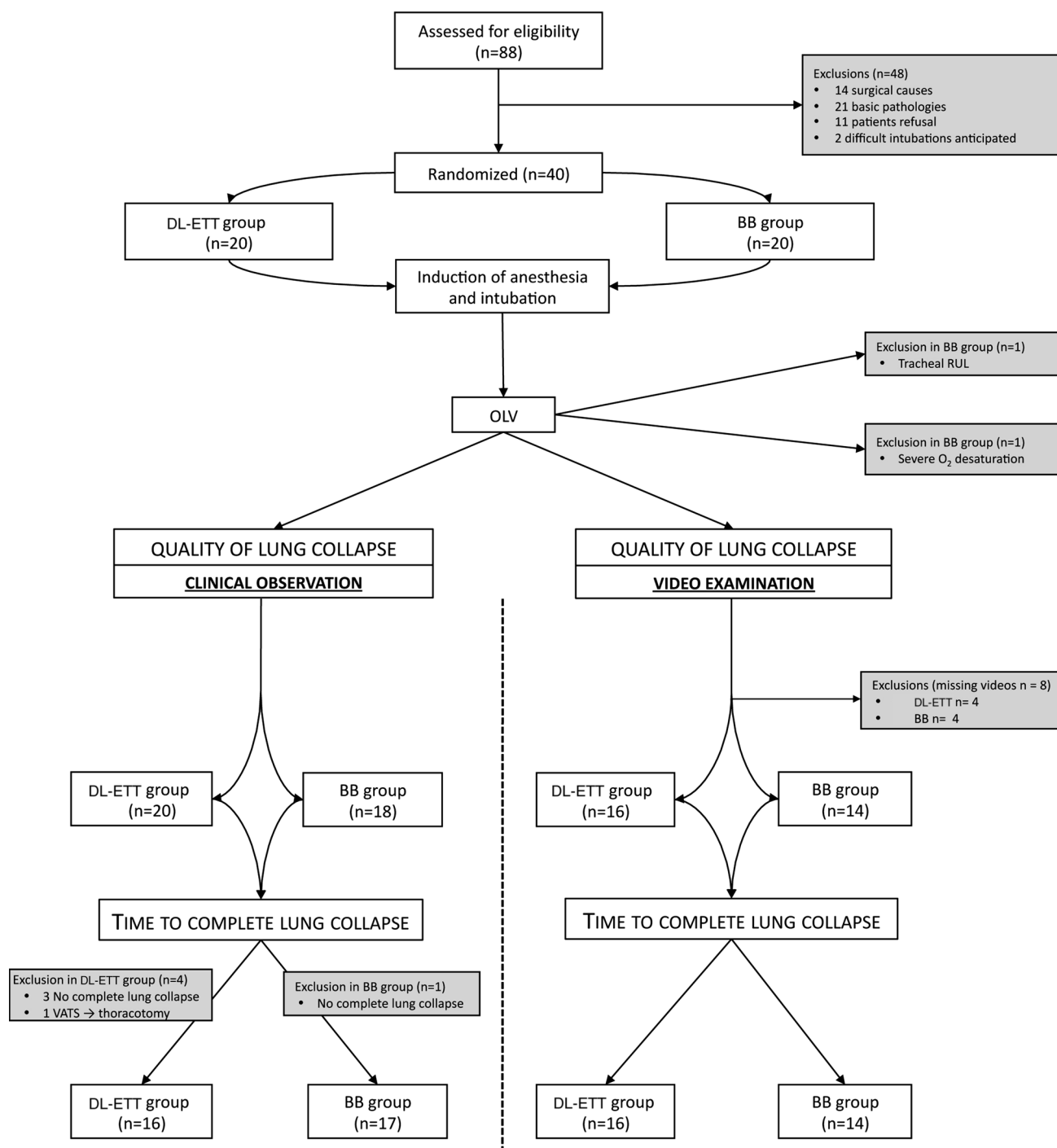


Fig. 2 CONSORT diagram

no conversion in thoracotomy secondary to poor exposure due to inadequate lung collapse.

Discussion

Our results show that, in patients having elective VATS, the time interval from pleural opening until objective assessment

of complete lung collapse is significantly faster with a BB than with a left-sided DL-ETT. In addition, when scoring the quality of lung deflation -in both the real-time and offline assessments- at five, ten, and 20 min from pleural opening, the BB showed a significantly better lung deflation than the left-sided DL-ETT. Furthermore, when asked which method was being used for lung isolation, the surgeons were correct only 37% of the time (with no differences between groups),

suggesting that the two devices could be used interchangeably without the surgeon noticing any differences.

Our study population is somewhat different from prior studies of OLV techniques as it included only patients having VATS. This study population represents over 95% of our hospital's elective intrathoracic procedures, and this appears to be a growing trend in many thoracic surgical centres.¹⁸ Contrary to most other published studies, we chose to select a homogenous population, and therefore, we excluded patients with pleural pathology, severe parenchymal disease, and previous thoracic surgery or thoracic radiotherapy as these conditions could interfere with lung collapse and introduce bias.

In addition to real-time clinical assessments of the quality of lung collapse, another strength of our study was our means for acquiring optimally objective data -i.e., the quality of lung collapse was assessed using both offline video review and clinical observation. Our definition of lung collapse was very conservative in that it meant complete collapse of all lung areas and was graded using a standardized visual scale (Fig. 1). Also, as there was substantial agreement between the three observers of video clips ($\kappa = 0.68$), we consider the video evaluation as being more valuable than the surgeon's direct clinical observation, which may be influenced by different factors during the surgery.

Table 1 Demographic and surgical characteristics

DATA	DL-ETT (<i>n</i> =20)	BB (<i>n</i> =18)
Age (yr)	63 (11)	62 (8)
Male, <i>n</i> (%)	9 (45)	8 (44)
Ideal Weight (kg)	69.6 (6.4)	68.2 (9.9)
BMI ($\text{kg}\cdot\text{m}^{-2}$)	27.9 (6.1)	28.3 (5.1)
FEV1/FVC (%)	71.4 (6.7)	71.9 (7.5)
FEV1 (%)	87.1 (19.2)	90.6 (6.8)
FVC (%)	96.5 (17.4)	98.6 (16.7)
Right-sided isolation, <i>n</i> (%)	10 (47.6)	11 (52.4)
Left-sided isolation, <i>n</i> (%)	10 (58.8)	7 (41.2)

Values are expressed as mean (standard deviation) unless otherwise indicated. BB = bronchial blockers; BMI = body mass index; DL-ETT = double-lumen endotracheal tubes; FEV1 = forced expiratory volume in one second; FVC = forced vital capacity

One novel aspect of our study was using two periods of apnea when using the BB for lung isolation; this represents a recent refinement in the BB technique. Indeed, prior publications have reported one period of apnea -i.e., prior to initiating OLV, and few have described the use of any apnea period prior to initiating OLV.⁸⁻¹⁰ They showed similar or inferior results compared with using the DL-ETT. The results we obtained by adding a second apnea period at the time of pleural opening showed a decrease in time to obtain complete lung collapse and an important increase in the quality of lung deflation. In our view, the addition of a second period of apnea synchronized with the surgical pleural opening is imperative to obtain optimal lung collapse with the BB during VATS.

Lung collapse following lung isolation occurs in two phases. The first phase of lung collapse occurs rather promptly (i.e., within the first few minutes) due to the inherent elastic recoil of the lung as soon as ambient air freely enters the thoracic cavity at the pleural opening. This rapid but partial collapse ceases presumably due to closure of small airways. In the second phase, lung collapse is dependent on continuous gaseous diffusion and secondary absorption atelectasis.¹⁸ Therefore, there are two possible explanations for the shorter time to obtain total lung collapse and better lung deflation observed with the BB.

First, the longer time period for lung deflation with a left-sided DL-ETT involves air movement from the mediastinal shifts during OLV with the non-dependent lung side open to room air. It is conceivable that, compared with the closed BB, significant quantities of O₂ in the lung are replaced due to passive inflow of ambient air into the non-dependent lung, which therefore impedes the second phase of lung deflation with the left-sided DL-ETT.

Another reason that could occur concurrently is the occasional anatomical obstruction that can happen at the distal portion of the bronchial lumen when the left-sided DL-ETT is used for left side lung isolation or at the distal extremity of the tracheal lumen when the left-sided DL-ETT is used for right side lung isolation. We regularly observe this anatomical obstruction during FOB when placing a left-sided DL-ETT once the patient is in the lateral position. Lateral positioning, as it relates to lung deflation, may

Table 2 Lung collapse data - time intervals from pleural opening until complete lung collapse

	DL-ETT	BB	mean difference	95% CI	<i>P</i>
Video Review	<i>n</i> =11 36.6 (29.1) min	<i>n</i> =14 7.5 (3.8) min	29.1 min	3.6 (1.8 to 7.2)	< 0.001
Clinical Evaluation	<i>n</i> =16 22.9 (21.4) min	<i>n</i> =17 10.3 (10.6) min	12.6 min	2.0 (1.1 to 3.8)	0.047

Values are expressed as mean (standard deviation). BB = bronchial blockers; CI = confidence interval; DL-ETT = double-lumen endotracheal tubes

Table 3 Quality of lung deflation obtained by video examinations

Video examinations	TIME (min)	0		5		10		20	
		BB <i>n</i> (%)	DL-ETT <i>n</i> (%)	BB <i>n</i> (%)	DL-ETT <i>n</i> (%)	BB <i>n</i> (%)	DL-ETT <i>n</i> (%)	BB <i>n</i> (%)	DL-ETT <i>n</i> (%)
Total (<i>n</i>)		14	16	14	16	11	14	14	16
No collapse	1	3 (21)	10 (63)	0 (0)	3 (19)	0 (0)	0 (0)	0 (0)	0 (0)
Partial collapse	2	10 (71)	6 (38)	6 (43)	12 (75)	3 (27)	12 (86)	0 (0)	10 (63)
Total collapse	3	1 (7)	0 (0)	8 (57)	1 (6)	8 (73)	2 (14)	14 (100)	4 (25)
<i>P</i> *value		0.04		0.004		0.005		< 0.001	

* Statistical significance threshold set at $P < 0.0125$ (Bonferroni correction). BB = bronchial blockers; DL-ETT = double-lumen endotracheal tubes

Table 4 Quality of lung deflation obtained by clinical observations

Clinical observations	TIME (min)	0		5		10		20	
		BB <i>n</i> (%)	DL-ETT <i>n</i> (%)	BB <i>n</i> (%)	DL-ETT <i>n</i> (%)	BB <i>n</i> (%)	DL-ETT <i>n</i> (%)	BB <i>n</i> (%)	DL-ETT <i>n</i> (%)
Total (<i>n</i>)		18	20	18	20	18	20	18	20
No collapse	1	1 (6)	2 (10)	0 (0)	1 (5)	0 (0)	0 (0)	0 (0)	0 (0)
Partial collapse	2	13 (72)	15 (75)	8 (44)	15 (75)	6 (33)	14 (70)	4 (22)	11 (55)
Total collapse	3	4 (22)	3 (15)	10 (56)	4 (20)	12 (67)	6 (30)	14 (78)	9 (45)
<i>P</i> *value		0.87		0.04		0.05		0.05	

* Statistical significance threshold set at $P < 0.0125$ (Bonferroni correction). BB = bronchial blockers; DL-ETT = double-lumen endotracheal tubes

induce a downward gravity-dependent movement of the hilum and produce variable obstruction of the distal endobronchial lumen or the tracheal lumen near the carina. With a BB, there is probably less chance of an anatomical obstruction of the distal endobronchial lumen of the SL-ETT. This is due to better support offered by the trachea and less influence from gravity compared with the bronchus. These speculative explanations need further clinical study for a better understanding of their significance.

Rescue suction was allowed only when the visual deflation score was at level 1 (i.e., poor deflation) and used only once in the BB group. Campos *et al.* used suction in more than 50% of lung isolation cases when using the BB and frequently when using the left-sided DL-ETT.⁴⁻⁶ Suction was frequently used in more than 50% of the published studies, only two studies did not use it in their protocol.^{8,10} Deliberately occluding the internal channel of the BB (small diameter, 2 mm; effective length, 67 cm), allows extrapolation of the results to every commercially available BB and confirms our impression that this channel does not participate passively in lung deflation.^{6,8,11}

There were some limitations to this study. We did not obtain data for the video examination from eight patients (four patients in each group) due to technical problems. Even with

these missing data, the results of the video examination data are in accordance with the clinical observations in favour of the BB. Another limitation is that our population was restricted to patients presenting good lung recoil, as patients with potentially altered lung recoil were excluded from the study. Nevertheless, patients with pulmonary pathologies associated with bad recoil correspond to a population in which the BB could be used, but rarely with optimal result.

Conclusion

This study shows that use of a BB (with two apnea periods) results in a faster time to obtain lung collapse and a superior quality of lung deflation when compared with use of a left-sided DL-ETT during elective VATS. Furthermore, in most patients, thoracic surgeons could not identify the type of device used for lung isolation. These results are relevant to clinical practice as this BB protocol is easily applicable in patients undergoing lung resection by VATS on both lungs. Furthermore, as the internal channel of the BB was occluded throughout the study, the results can be extrapolated to a wide variety of BBs.

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Conflicts of interest None declared.

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Editorial responsibility This submission was handled by Dr. Hilary P. Grocott, Editor-in-Chief, *Canadian Journal of Anesthesia*.

Appendix

The model, which has been described in a previous publication,¹⁹ is based on the probability of observing a given lung deflation score at a given time according to the following relationship:

$$P(\text{score} \geq dS) = \frac{\text{Time}^N}{\text{Time}^N + \text{Time}_{50,dS}^N}. \quad (1)$$

where *Time* is the elapsed time since the initiation of OLV; *N* is the Hill coefficient related to the steepness of the relationship; *dS* is the deflation score; and *Time*_{50,*dS*} is the time when there is a 50% chance of observing a deflation score of *dS* or greater.

A specific case of equations 1 is equation 2.

$$P(\text{score} \geq 1) = 1 \quad (2)$$

Equation 2 is obvious since the probability of observing a score of 1 or greater is 100%.

Equation 1 predicts the probability of observing a score greater or equal to a given score rather than observing a given score. The probability of observing a score equal to 1, 2, or 3 is derived from the following equation.

$$P(\text{score} = dS) = (\text{score} \geq dS) - P(\text{score} \geq dS + 1) \quad (3)$$

where *dS* is equal to 1, 2, or 3.

From equations 2 and 3:

$$P(\text{score} = 1) = 1 - P(\text{score} \geq 2) \quad (4)$$

$$P(\text{score} = 2) = P(\text{score} \geq 2) - P(\text{score} \geq 3) \quad (5)$$

$$P(\text{score} = 3) = P(\text{score} \geq 3) \quad (6)$$

Equation 6 is self-evident since there is no score possible above 3.

The likelihood (LL) of the model is the product of the probability of each observed deflation score. Parameters *Time*_{50,*dS*} and *N* were estimated by using the solver function of Microsoft Excel to minimize the objective function -2LL.

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Choosing a Lung Isolation Device for Thoracic Surgery: A Randomized Trial of Three Bronchial Blockers Versus Double-Lumen Tubes

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BACKGROUND: There is no consensus on the best technique for lung isolation for thoracic surgery. In this study, we compared the clinical performance of three bronchial blockers (BBs) available in North America with left-sided double-lumen tubes (DLTs) for lung isolation in patients undergoing left-sided thoracic surgery. **METHODS:** One hundred four patients undergoing left-sided thoracotomy or video-assisted thoracoscopic surgery were randomly assigned to one of the four lung isolation groups ($n = 26/\text{group}$). Lung isolation was with an Arndt® wire-guided BB (Cook® Critical Care, Bloomington, IN), a Cohen Flexi-tip® BB (Cook Critical Care) or a Fuji Uni-blocker® (Fuji Systems, Tokyo) or with a left-sided DLT (Mallinckrodt Medical, Cornamadda, Athlone, Westmeath, Ireland). Anesthetic management and lung isolation were performed according to a standardized protocol. Each group was randomly subdivided into two subgroups ($n = 13/\text{subgroup}$): immediate suction (at the time of insertion of the lung isolation device) (Subgroup I) or delayed suction (20 min after insertion of the lung separation device) (Subgroup D) according to when suction was applied to the BB suction channel or the bronchial lumen of the DLT. Using a verbal analog scale, lung collapse was assessed by the surgeons, who were blinded to the lung isolation technique.

RESULTS: There was no difference among the lung isolation devices in lung collapse scores at 0 ($P = 0.66$), 10 ($P = 0.78$), or 20 min ($P = 0.51$) after pleural opening. The time to initial lung isolation was less for DLTs (93 ± 62 s) than BBs (203 ± 132) ($P = 0.0001$). There were no differences among the BBs in the time to lung isolation ($P = 0.78$). There were significantly more repositions after initial placement of the lung isolation device with BBs (35 incidents) than with DLTs (two incidents) ($P = 0.009$). The Arndt BB required repositioning more frequently (16 incidents) than the Cohen BB (8) or the Fuji BB (11) ($P = 0.032$).

CONCLUSIONS: The three BBs provided equivalent surgical exposure to left-sided DLTs during left-sided open or video-assisted thoracoscopic surgery thoracic procedures. BBs required longer to position and required intraoperative repositioning more often. The Arndt BB needed to be repositioned more often than the other BBs.

(Anesth Analg 2009;108:1097-101)

One-lung ventilation (OLV) is often performed during thoracic surgery to facilitate surgical exposure. The most common techniques for achieving OLV are a double-lumen endobronchial tube (DLT) or bronchial

blockers (BBs). Within the past decade, three new independent BB have become available (Fig. 1).¹⁻³ The comparative clinical performance of these BBs has not yet been studied. The purpose of this study was to compare the efficacy of these BBs with DLTs for achieving lung collapse. It is generally accepted that BBs perform better clinically when positioned in the left mainstem bronchus (LMB) versus the right bronchus.⁴ Thus, this study was limited to left-sided thoracic procedures to optimize the conditions for BB function. We further evaluated the time required to achieve correct lung isolation and the number of device repositionings needed to maintain OLV.

METHODS

After approval by the hospital's Research Ethics Board, written informed consent was obtained from patients undergoing left-sided thoracotomies or

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The bronchial blockers were provided free of cost to the institution (Toronto General Hospital, University Health Network, Toronto, Canada).

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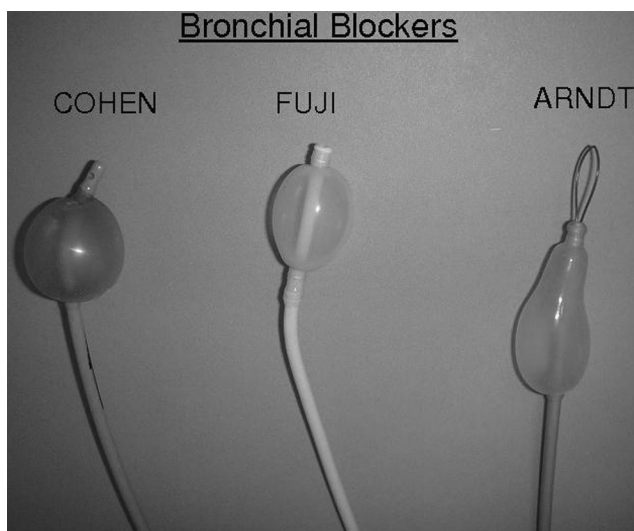


Figure 1. The three different types of bronchial blockers used in the study. The Cohen Tip-Deflecting Endobronchial Blocker 9F (Cook® Critical Care, Bloomington, IN) allows anesthesiologists to establish single-lung ventilation by directing its flexible tip left or right into the desired bronchus using a control wheel device on the proximal end of the blocker in combination with fiberoptic bronchoscope guidance.¹ It is available only in 9F size. The wire-guided endobronchial blocker (Arndt® blocker; Cook® Critical Care) introduced in 1999, contains a wire loop in the inner lumen; when used as a snare with a fiberoptic bronchoscope (FOB), it allows directed placement.² The snare is then removed and a 1.4-mm lumen may be used as a suction channel or for oxygen insufflation. The external diameter is 9F. Sizes 7F and 5F are also available. The Fuji Uni-blocker®, 9F, (Fuji Corp., Tokyo, Japan) has a fixed distal curve, which allows it to be rotated for manipulation into position with FOB guidance. It is also available in a 5F size. Unlike its predecessor, the Univent, the Uni-blocker is used with a standard endotracheal tube.³

video-assisted thoracoscopic surgery for which periods of OLV exceeding 30 min were deemed necessary. Subjects were consecutive consenting patients scheduled for lung or esophageal surgery with no contraindication to the use of a DLT, BB, or the anesthetic protocol. The patients were randomly assigned immediately before induction of anesthesia to one of the four study groups to undergo OLV with an Arndt® BB (Cook® Critical Care, Bloomington, IN), a Cohen® BB (Cook Critical Care), a Fuji® BB (Fuji Systems, Tokyo), or a left-sided DLT (Mallinckrodt Medical, Cornamaddy, Athlone, Westmeath, Ireland). Each of the four lung isolation groups were further subdivided into two subgroups to receive either immediate suction (I) (−20 cm H₂O applied at the start of lung isolation) to the DLT bronchial lumen or the BB suction channel or delayed suction (D) (applied 20 min after pleural opening). For the Arndt BB the wire loop was removed to use the channel for suction.

Anesthesia Protocol

After placement of standard monitors including a radial arterial catheter and administration of oxygen (F_{IO₂} = 1.0 for 3 min), anesthesia was induced with

propofol (1–2 mg/kg), and maintained with fentanyl (5–10 µg/kg) and one minimum alveolar concentration sevoflurane in oxygen (F_{IO₂} 1). Rocuronium 1 mg/kg was used for muscle relaxation with repeat 10 mg boluses as required. Most of the patients had thoracic epidurals placed before induction for postoperative analgesia.

Lung Isolation Methods

The BBs and DLTs were placed by thoracic anesthesia fellows (physicians doing 1 yr of specialized postgraduate training) supervised by staff thoracic anesthesiologists. After induction of anesthesia, the patients' tracheas were intubated using a Macintosh no. 3 laryngoscope with either a 8.0-mm internal diameter endotracheal tube (ETT) (BB groups) or an appropriately sized left DLT (females <160 cm height: 35F; females >160 cm: 37F; males <170 cm: 39F; males >170 cm: 41F). All BBs were placed via the ETT according to the manufacturers' recommended techniques using a pediatric fiberoptic bronchoscope (FOB). The BBs were positioned distally in the LMB. The DLTs were passed to an appropriate depth according to the patient's height⁵ and tube position was adjusted using a FOB, initially via the tracheal lumen and then via the bronchial lumen.^{6,7} The tracheal cuff was then inflated. After placement, the cuff of the BB or the bronchial cuff of the DLT was inflated with FOB surveillance and OLV in all patients in the supine position was begun using volume-controlled ventilation (tidal volume of 5–6 mL/kg ideal body weight with the respiratory rate adjusted to maintain the PETCO₂ in the normal range, F_{IO₂} 1). The surgeons were absent from the operating room during DLT or BB placement and were blinded to the airway device by means of a sheet placed over the lung isolation device. The patients were then turned to the right lateral decubitus position for surgery and the position of the lung isolation device confirmed by FOB. The lung isolation device was repositioned if the BB or the bronchial cuff of the DLT was not appropriately positioned in the left bronchus.

Study End Points

The time from beginning of laryngoscopy to lung isolation was recorded. The thoracic surgeons using a verbal analog scale, assessed the lung collapse (lung collapse scores [LCS], 0 = no collapse, to 10 = complete collapse). The LCS was assessed and recorded as they opened the pleura during the procedure (LCS 0), and at 10 min, (LCS 10), and 20 min (LCS 20) after opening the pleura. If the lung collapse was not satisfactory, the FOB was passed to diagnose and correct the problem. The number of repositions of the lung isolation device after initial placement, airway pressures, tidal volumes, duration of surgery, and the arterial blood gases 20 min after pleural opening were recorded.

Table 1. Ventilation and Airway Data (mean $\pm$ sd) for Double-Lumen Tube (DLT) Group Versus Bronchial Blockers (BBs) Combined

	DLT <i>n</i> = 26	BBs <i>n</i> = 78	<i>P</i>
TLC (% predicted)	107 $\pm$ 24	106 $\pm$ 19	0.88
FEV1(% predicted)	88.3 $\pm$ 21.9	92.5 $\pm$ 22.6	0.51
Height (cm)	167 $\pm$ 8	171 $\pm$ 9	0.22
Weight (kg)	74.7 $\pm$ 13	82.8 $\pm$ 20	0.14
BMI (kg/m ²)	26.7 $\pm$ 4.2	28 $\pm$ 6	0.70
LMB angle to trachea (degrees)	38.5 $\pm$ 8	39 $\pm$ 7.5	0.59
Mallampati score	1.5 $\pm$ 0.76	1.36 $\pm$ 0.65	0.40
LMB length (cm)	4.12 $\pm$ 0.59	4.7 $\pm$ 0.95	0.015*
Time to lung isolation (s)	92.6 $\pm$ 62	203 $\pm$ 132	0.0001*
pHOLV	7.38 $\pm$ 0.06	7.34 $\pm$ 0.06	0.003*
Paco ₂ OLV (mm Hg)	42.3 $\pm$ 9.4	49.3 $\pm$ 16	0.04*
Pao ₂ OLV (mm Hg)	195 $\pm$ 81	188 $\pm$ 81	0.68
PAW OLV (cm H ₂ O)	18.6 $\pm$ 5.5	21 $\pm$ 5.5	0.07*
TV OLV (mL)	413 $\pm$ 96	421 $\pm$ 107	0.73
Respiratory rate OLV	12	14	0.05*

TLC = total lung capacity; FEV1 = forced expiratory volume in 1 s; BMI = body mass index; LMB = left main bronchus; OLV = one-lung ventilation; PAW = peak airway pressure; TV = tidal volume.

Other variables that were recorded included the Mallampati score, preoperative pulmonary spirometry results, and the angle of the LMB to the trachea and length of LMB on preoperative chest imaging. The angle and length of the LMB were measured by the anesthesiologist using the on-screen program of the radiology server.

Power Calculation and Data Analysis

Based on the data of Campos and Kernstein⁸ showing a mean time for placement of the Arndt BB of 200 s, and using a clinically relevant difference in mean placement of 60 s, 25 patients were required per group to have an estimated α error of 0.05 and β error of 0.2.⁹ To allow for an even number of patients in each suction subsection, 26 patients were recruited to each lung isolation technique group.

Data analyses of LCSs among the groups were with ANOVA (Tukey test was for multiple comparisons). We used analysis of covariance for covariate adjustment with regard to LCS. The number of DLT or BB repositionings was compared using the Fisher's exact test. Other continuous data were evaluated using the student *t*-test, and other dichotomous data with Fisher's exact test. *P* values <0.05 indicate statistical significance.

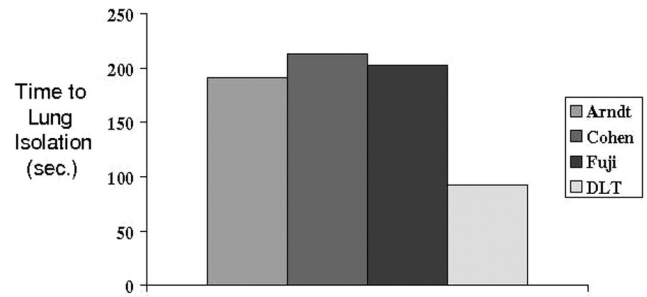


Figure 2. Mean time to lung isolation (s) with the different devices. The time to lung isolation with double-lumen tube (DLT) (93 $\pm$ 62 s) compared with bronchial blockers (BBs) (203 $\pm$ 132 s), *P* = 0.0001. The mean time to lung isolation for the Arndt BB was 191 $\pm$ 131 s, for the Cohen 204 $\pm$ 144 s, and for the Fuji 213 $\pm$ 144 s (*P* = 0.78).

RESULTS

One hundred six patients were recruited for the study. Two patients, one in DLT-D group (lung adhesions preventing collapse) and one in the Arndt-I group (inoperable lung cancer) were excluded from the study. These patients were excluded before the study period. Other patients were subsequently recruited and randomized to replace these two subjects. Data were analyzed from 104 patients.

Patient demographics and other preoperative data are listed in Table 1. The groups were similar with regard to age, sex, weight, body mass index, pulmonary function tests, airway grade, LMB angle to the trachea, and types of surgical procedures (Table 2).

Times to lung isolation are shown in Figure 2. The time (mean $\pm$ sd) to lung isolation was significantly less for DLTs (93 $\pm$ 62 s) than BBs (203 $\pm$ 132 s), *P* = 0.0001. There was no difference between the BBs in the time to lung isolation. The mean time to lung isolation for the Arndt BB was 191 $\pm$ 131 s, for the Cohen 204 $\pm$ 144 s and for the Fuji 213 $\pm$ 144 s (*P* = 0.78). Lung isolation scores data are shown in Figure 3. There was no difference among four lung isolation devices for LCS at 0 min (*P* = 0.66), 10 min (*P* = 0.78), and 20 min (*P* = 0.51) after pleural opening.

Data on the number of lung isolation device repositionings are shown in Figure 4. There were significantly more frequent repositionings with the BBs (35 incidents) compared with DLTs (two incidents) (*P* = 0.009). The Arndt BBs needed to be repositioned 16 times, the Fuji BB 11 times and the Cohen BB 8 times. The Arndt BBs needed to be repositioned more often than the other BBs (*P* = 0.032). Early Suction applied

Table 2. Surgical Procedure and Airway Device

Surgical procedure	Arndt® BB	Coben® BB	Fuji® BB	DLT	<i>P</i>
Thoracotomy lobectomy	11	10	11	13	1
Thoracotomy wedge resection	6	5	2	5	0.25
Thoracotomy pneumonectomy	1	0	1	1	1
Thoracotomy esophageal surgery	4	6	5	1	0.35
Video-assisted thoracoscopic surgery	4	5	7	6	0.5

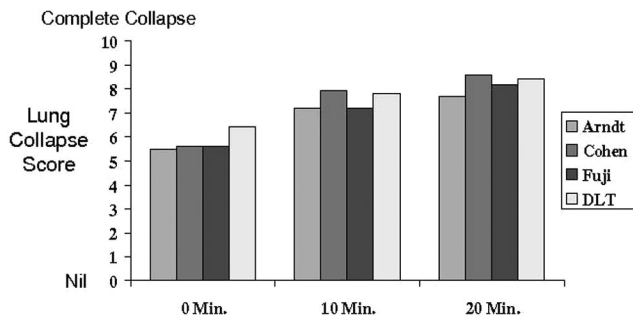


Figure 3. Lung collapse scores with the different devices at 0, 10, and 20 min after pleural opening. LCS at 0 min ($P = 0.66$), 10 min ($P = 0.78$), and 20 min ($P = 0.51$) after chest opening for the lung isolation devices.

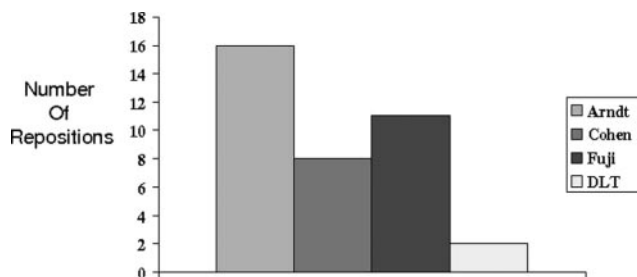


Figure 4. Number of fiberoptic repositions of the lung isolation devices. Bronchial blockers (BBs) (35 repositioning incidents) compared with double-lumen tubes (DLTs) (two repositioning incidents) ($P = 0.009$). The Arndt® BBs repositioned 16 times, the Fuji® BB 11 times, and the Cohen® BB 8 times. The Arndt® BB needs to be repositioned more frequently than the other BBs ($P = 0.032$).

to the Cohen BB ($P = 0.018$) and DLT ($P = 0.019$) significantly increased the LCS when compared with late suction but not with the Arndt BB or Fuji BBs (Fig. 5).

There was a significant difference in the mean peak airway pressures between BB (19 cm H₂O) and DLT (16 H₂O). There was no difference in the mean tidal volumes among the groups ($P = 0.66$). The pH was significantly lower ($P = 0.007$) and Paco₂ significantly ($P = 0.015$) higher in the BB group than in the DLT group (Table 1).

DISCUSSION

Left-sided DLT tubes are commonly used for lung isolation. There has been a recent increase in interest in the use of BBs for OLV after the introduction of new blocker designs and because of the widening scope of surgical procedures requiring lung isolation, such as minimally invasive cardiac procedures and transthoracic spine surgery.¹⁰ Although, widely used clinically, DLTs are associated with several limitations, including difficulty with insertion and positioning in patients with abnormal upper or lower airway anatomy and in patients with difficult airways. Further, the use of DLTs requires the change to a single-lumen ETT at the completion of surgery if the patient requires postoperative ventilatory support. This may present challenges in the presence of facial edema,

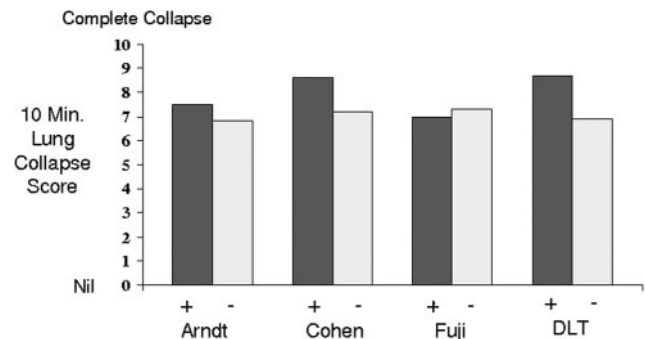


Figure 5. Effect of Immediate (+) or Delayed (-) suction (-20 cm H₂O) on lung collapse scores. Early Suction (+ in graph) applied to the Cohen™ bronchial blocker (BB) ($P = 0.018$) and double-lumen tube (DLT) ($P = 0.019$) significantly increased the lung collapse scores when compared with late suction (- in graph) but not with the Arndt™ or Fuji™ BBs.

secretions, laryngeal trauma from the initial intubation and large fluid shifts during surgery. Moreover, DLTs, when compared with a single-lumen ETT, are associated with more airway trauma, leading to postoperative hoarseness and throat pain.¹¹ The new BBs, therefore, offer a reasonable alternative to DLTs in such clinical situations. Although the efficacy of right- or left-sided DLT and Univent tubes® has been reported,^{12,13} there has been no prospective study comparing the effectiveness of lung isolation with the new BBs and DLTs.

This study demonstrated that the tested BBs required an average of 110 s longer to position than DLTs ($P = 0.0001$) (Fig. 2). However, once lung isolation was achieved, the overall clinical performance, as determined by an objective assessment of lung collapse, was equivalent for all four devices. Further, we found no significant differences among the BBs in time to lung isolation or lung isolation scores. There were more repositionings of the lung isolation device with the BBs compared with the DLTs ($P = 0.009$). The Arndt BB needed to be repositioned more often than the other BBs ($P = 0.032$). This may have been due to the elliptical shape of the bronchial cuff in the Arndt BB compared with the spherical cuffs in the Cohen BB and Fuji BB. Subsequent to the introduction of the elliptical Arndt blocker used in this study, introduced a version of the Arndt blocker with a spherical balloon. The spherical blocker is produced in a range of sizes 9, 7, and 5F, whereas the elliptical blocker comes in the 9F size only. There are no published clinical studies comparing the two versions of the Arndt blocker.

The suction channel of the Cohen BB has multiple distal orifices, which may be why early suction improves lung collapse in these patients compared with the other BBs ($P = 0.018$) (Fig. 5). The larger single bronchial lumen of the DLT (6–9 mm) may explain why early suction showed some benefit ($P = 0.019$) (Fig. 5). The failure of suction to improve LCS in the Arndt BB in this study is not consistent with results

published by Campos and Kernstein.⁸ A potential criticism of this study is that the level of suction used to try to increase the rate of lung collapse is low. Some clinicians use high levels of suction for this purpose. However, direct wall suction pressures (−200 mm Hg) have been shown to be harmful to airway mucosa.¹⁴ We chose to use a suction of −20 cm H₂O.

The LCSs were assessed in this study at pleural opening and for the next 20 min. Because we consider this period to be clinically the most relevant. The equivalent rate of lung collapse (Fig. 3) with BBs and DLTs in this study is in disagreement with previous studies.^{9,15} The improved performance of BBs in this study compared with the other studies of BBs,^{9,15} in which the Arndt™ BB took longer to deflate the lung compared with DLT, may be related to the anesthetic protocol. The operative lung was collapsed during a period of apnea and after careful administration of oxygen and ventilation with a F_{IO₂} of 1.0. Residual nitrogen in the operative lung from prior ventilation with air/oxygen mixtures may delay collapse. Finally, we found that the mean airway pressures with the BBs were higher than with the DLTs. Because the tidal volumes were similar, this may indicate that the airflow resistance of a single-lumen ETT with a BB is higher than the tracheal lumen of a DLT.

A limitation of this study is that postgraduate anesthesia fellows performed the lung isolation procedures. This group of trainees was relatively homogeneous in terms of clinical experience. The fellows had more experience with DLTs than BBs before the study and this may be, in part, responsible for the longer time required for lung isolation with the BBs. Experts in thoracic anesthesia have performed most of the clinical studies of BBs.^{9,11} However, in the study done by Campos and Kernstein⁸ the time to place an Arndt BB was approximately 200 s, which is comparable with the time it took to place the BBs in this study. The staff thoracic anesthesiologists each had more than 10 yr of clinical experience and were familiar with all devices used before the study. They confirmed the final position of the lung isolation device; therefore, the lack of experience of the operators cannot explain the subsequent increased need for repositioning of the BBs.

In summary, the three BBs provided equivalent surgical exposure to left-sided DLTs during left-sided open or video-assisted thoracoscopic surgery thoracic procedures. BBs required longer to position and required more frequent intraoperative repositioning. The Arndt BB had to be repositioned more often than the other BBs.

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