Efficiency, Efficacy, and Safety of EZ-Blocker Compared with Left-sided Double-lumen Tube for One-lung Ventilation

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Abstract

Background: Double-lumen tubes (DLTs) or bronchial blockers are commonly used for one-lung ventilation. DLTs are sometimes difficult or even impossible to introduce, and the incidence of postoperative hoarseness and airway injuries is higher. Bronchial blockers are more difficult to position and need more frequent intraoperative repositioning. The design of a Y-shaped bronchial blocker, the EZ-Blocker (Teleflex Life Sciences Ltd., Athlone, Ireland) (EZB), combines some advantages of both techniques. The objective of this study was to assess whether EZB performs clinically better than left-sided DLTs (Broncho-cath; Mallinckrodt, Athlone, Ireland) without causing more injury. Primary outcome was the frequency of initial malpositions.

Methods: Eligible patients were adults scheduled for surgery requiring one-lung ventilation who met criteria for placement of both devices. In this parallel trial, 100 consecutive and blinded patients were assigned randomly using a computer-generated list to two groups. The incidence of malposition and ease and time of placement were recorded. Blinded assessors investigated quality of lung deflation, postoperative complaints, and damage to the airway.

Results: Placement of a DLT was unsuccessful twice. The incidence of initial malposition was high and comparable between EZBs (37 of 50) and DLTs (42 of 49) (P = 0.212). Placing single-lumen tubes and EZBs took more time but was rated easier. Quality of lung deflation was comparable. Fewer patients in the EZB group complained of sore throat at day 1. There was a higher incidence of tracheal hematoma and redness and bronchial hematoma in the DLT group.

Conclusions: The EZB is an efficient and effective device for one-lung ventilation and causes less injury and sore throat than a DLT.

What We Already Know about This Topic

- Double-lumen tubes are usually used for lung isolation

What This Article Tells Us That Is New

- A bronchial blocker was equally efficacious, caused less injury to the tracheal and bronchial mucosa, and caused fewer sore throats than double-lumen tubes

LUNG isolation techniques are used to facilitate one-lung ventilation (OLV) in patients undergoing thoracic surgery, to protect one lung from contamination or hemorrhage in the contralateral lung, and for differential ventilation of the lungs. Commonly used for lung isolation is a double-lumen tube (DLT), which can be placed using only laryngoscopy and auscultation. It is recommended that bronchoscopy be used to verify the correct position because the incidence of malpositions is high.[1–5] The major disadvantage of DLTs is the often difficult placement because of the larger diameter; as a consequence, patients often complain of hoarseness or sore throat.[6] There is also a potential for minor laryngeal, tracheal, and bronchial trauma.[6] Major traumas such as bronchial ruptures have been described.[7] Compared with other techniques, a DLT has to be replaced by a single-lumen tube (SLT) if prolonged postoperative ventilation is necessary.

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Received from the Department of Anesthesiology, Pain and Palliative Medicine, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands. Submitted for publication March 7, 2012. Accepted for publication November 8, 2012. We obtained 50 EZ-Blockers from the former manufacturer (AnaesthetIQ BV, Rotterdam, The Netherlands) for an equal price as 50 DLTs. This work has been presented at the Annual Symposium of the Dutch Cardioanesthesiology Association, Baarlo, The Netherlands, November 12, 2011.

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Alternatively, a bronchial blocker (BB) can be used for lung isolation. This is a balloon-tipped semirigid catheter. Different types are available (*e.g.*, the wire-guided endobronchial Arndt blocker [Cook Critical Care, Bloomington, IN], the Cohen flex-tip blocker [Cook Critical Care], and the Univent torque control blocker [Vitaid, Lewiston, NY]. The BB is positioned in a bronchus with the aid of bronchoscopy. A BB is normally placed through the inside of an SLT. These types of blockers are not easy to position and frequently dislocate during repositioning of the patient or during surgical manipulation.[8] It is not easy to alternate OLV to either lung (*e.g.*, for protecting the contralateral lung from overinflation during reexpansion of the ipsilateral lung or during bilateral procedures).

To solve these problems, a novel type of BB, the EZ-Blocker (Teleflex Life Sciences Ltd., Athlone, Ireland) (EZB) has been developed.[9] The EZB is also a semirigid catheter, but it has two distal extensions, both with an inflatable cuff and a central lumen (fig. 1). Advantages are believed to be the ease of placement through an SLT (minimum, 7-mm ID) and the ease of putting the distal extensions in the correct place, combined with fewer dislocations during repositioning the patient and during surgical manipulations. These improvements are attributable to the fact that the blocker anchors itself on the carina with the two extensions (fig. 2). Furthermore, one size of EZB will fit almost all adult patients, whereas selecting the best size for a DLT is rather complicated.[10,11] The cuff pressure of the EZB at adequate cuff volume is high and could be responsible for mucosal injury at the mainstem bronchi.

The EZB has been evaluated in a clinical study.[4] This is the first clinical study to evaluate with a comprehensive examination of the airway both the efficacy and safety of the device. We hypothesize that the EZB performs clinically better than a DLT for lung isolation without causing more injury to the patient.

Materials and Methods

This study was approved by the local ethical committee on research involving human subjects for the region of Arnhem-Nijmegen (Nijmegen, The Netherlands) (NL30799.091.09) and registered at ClinicalTrials.gov (NCT01073722). This single-site study took place at a university hospital in The Netherlands and started recruitment in March 2010, and final enrollment was in March 2011. Patients were recruited from the operation planning list. After informed written consent, American Society of Anesthesiologists physical status 1–3 patients aged 18 yr or older undergoing surgical procedures

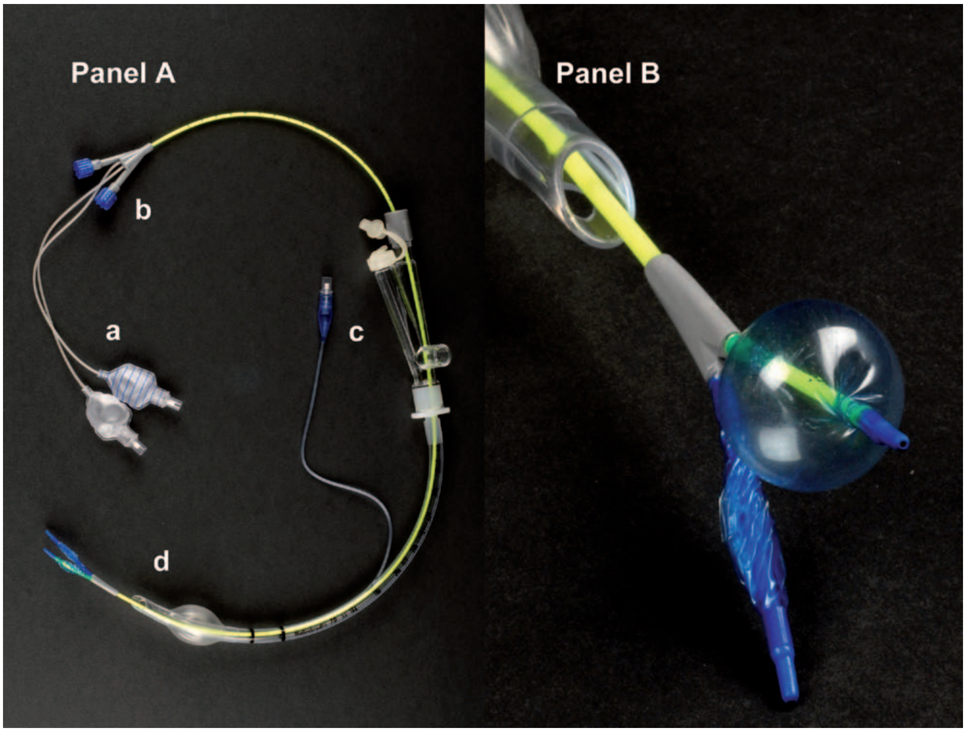

Fig. 1. EZ-Blocker (EZB) placed through a single-lumen tube (7-mm ID). (*A*) An overview of the EZB, a 7-French, 75-cm, 4-lumen catheter. At the proximal end are (*a*) two differently colored pilot balloons with one-way valves. The colors correspond to the color of the distal balloons. Then, there are (*b*) two continuous positive airway pressure ports for the lumen for administration of oxygen. Next, the EZB enters (*c*) the multiport adaptor with a screw cap that seals the EZB, a port for a bronchoscope or suction catheter, and connections for the endotracheal tube and ventilation devices. At the distal end are (*d*) extensions with balloons (deflated). (*B*) Close-up view of the distal end. The EZB is protruding from the endotracheal tube. The two distal extensions are differently colored. One of the polyurethane high-pressure balloons is inflated. The distal tips of the extensions are made of soft material and have a central lumen of 0.7 mm. Photographs taken by Anja Prischmann, medical photographer, and used with permission.

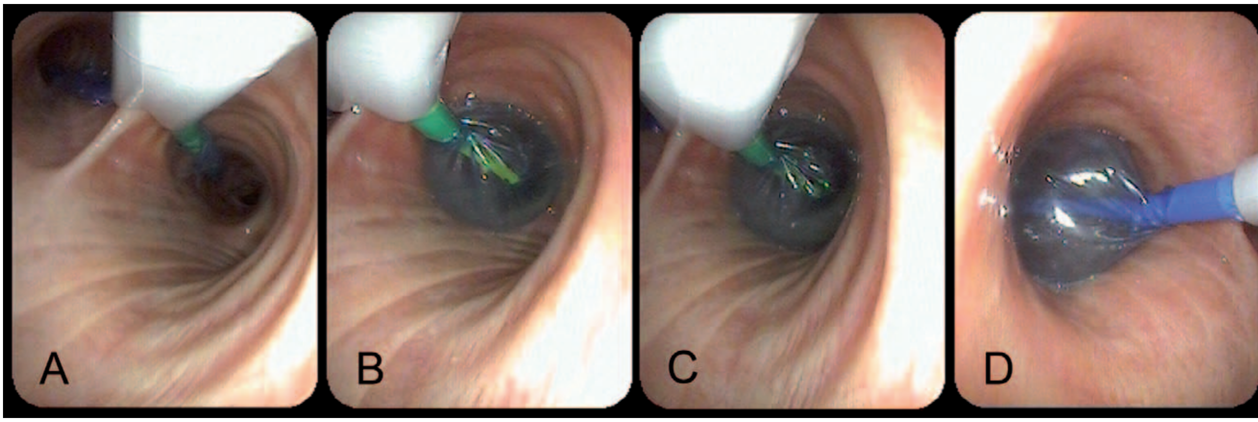

Fig.2. View with a 3.7-mm videobronchoscope of an EZ-Blocker situated in the trachea and bronchi of a patient. (*A*) View on the main carina. The bifurcation of the distal extensions rests on the main carina. The yellow extension is in the right mainstem bronchus and the blue extension is in the left mainstem bronchus. (*B*) The balloon in the right mainstem bronchus is insufflated with 7 ml of air and is blocking the bronchus intermedius. The aperture of the right upper lobe bronchus is still visible. (*C*) An additional 7 ml is insufflated and the balloon is also blocking the right upper lobe bronchus. (*D*) The balloon in the left mainstem bronchus is insufflated with 10 ml of air.

requiring a left-side DLT for OLV were included. Patients with known lesions along the path of the left-sided DLT or the EZB, anticipated difficult intubation (Mallampatti score ≥3), presence of tracheostomy, and patients requiring absolute lung separation or scheduled for bronchial sleeve resection or pneumonectomy were excluded from the study. The study was set up as a parallel design with the aim of identifying the superiority of the new device. Consecutive patients requiring surgery were allocated 1:1 into two groups—the DLT or the EZB group—using a computer-generated "simple" randomization. Codes were kept in numbered envelopes. An independent data safety monitoring board was not instituted. Patients were blinded with regard to the device used.

All patients received midazolam and paracetamol orally for premedication. In the operating room, they received standard monitoring, intraarterial pressure monitoring, and bispectral index monitoring. Patients scheduled for thoracotomy received an epidural anesthetic at the T3–T4 or T4–T5 level using 20 mg bupivacaine and 20 μg sufentanil. After 3 min, preoxygenation patients received 1.5–3 mg/kg propofol, 0.6 mg/kg rocuronium, 10 μg sufentanil, and antibiotics IV. An I-gel® laryngeal mask airway (Intersurgical, Uden, The Netherlands) was inserted 2 min later. Anesthesia was maintained with propofol at 4–10 $mg \cdot kg^{-1} \cdot hr^{-1}$ IV.

Before intubation, a pulmonologist observed the status of the airway with an Olympus BF-3C40 or 3C160 bronchoscope (Olympus America Inc., Melville, NY) through the laryngeal mask airway. Injuries were classified[6] (table 1) and written on a chart. A video movie was stored for later comparison. Pulmonologists participated in this study because they are very experienced bronchoscopists. It was important for this study to avoid damaging the airway by the bronchoscopy itself. The pulmonologists had to judge the videos afterward and logically they produced the videos themselves.

Four anesthesiologists experienced with both techniques performed placement of the devices after removal of the laryngeal mask airway. Surgeons were absent from the operating room during tube placement and were blinded to the device used.

The correct size of DLT was extracted from the diameter of the left mainstem bronchus using computed tomography if available, or preoperative anteroposterior chest radiography using the diameter 1 cm beyond the carina with a −10% correction. If not clearly visible on radiography, the tracheal width at the level of the clavicles was measured and the following formula was used[10]: left mainstem bronchus diameter (mm) = (0.45) (tracheal width [mm]) + 3.3 mm. If the diameter of the left mainstem bronchus was 12, 13, or greater than 14 mm, a DLT size 35-, 37/39-, and 41-French, respectively, was chosen.[12] The estimated depth of insertion was derived from the following formula[13]: depth DLT (cm) = 12 + length patient (cm) × 10^{-1}. The styletted DLT without a carinal hook (Broncho-cath; Mallinckrodt, Athlone, Ireland) was introduced into the glottis *via* direct laryngoscopy. After the bronchial cuff passed the vocal cords, the stylet was removed and the tube was rotated 90 degrees toward the left. The tube was advanced until slight resistance was encountered. The pulmonologist inserted a bronchoscope to verify the position of the DLT tube.

Before EZB placement, a SLT (Hi-contour Tracheal Tube; Mallinckrodt), size 7 or 8 for women and size 8 or 9 for men, was introduced *via* direct laryngoscopy. The cuff of the tube had to be visible just below the vocal cords. A multiport adaptor (length, 11 cm) was attached to the tube. The EZB was lubricated with silicone spray and advanced through the tube until slight resistance was encountered after the tip emerged from the SLT. A pulmonologist verified the position of the SLT and the EZB using a bronchoscope.

The primary outcome of the study is the incidence of malposition detected by bronchoscopy after initial insertion. A

Table 1. Airway Injury

	Preoperative		Postoperative		Difference between DLT and EZB Using Preoperative and Postoperative Difference (*P* Value)
	DLT (n = 48)	EZB (n = 50)	DLT (n = 48)	EZB (n = 50)	
Vocal cord thickening					
Normal	46	48	42	44	0.962
Small lesions	1	1	6	4	
Large lesions	1	1	0	2	
Vocal cord redness					
Normal	48	49	43	48	0.140
Small lesions	0	1	5	2	
Large lesions	0	0	0	0	
Vocal cord edema					
Normal	44	48	32	35	0.776
Small lesions	3	2	13	9	
Large lesions	1	0	3	6	
Vocal cord erythema					
Normal	46	50	43	49	0.081
Small lesions	0	0	3	1	
Large lesions	0	0	2	0	
Vocal cord hematoma					
Normal	47	49	39	42	0.838
Small lesions	1	1	6	2	
Large lesions	0	0	3	6	
Vocal cord bleeding					
Normal	48	50	48	50	1.000
Small lesions	0	0	0	0	
Large lesions	0	0	0	0	
Vocal cord granuloma					
Normal	48	50	48	50	1.000
Small lesions	0	0	0	0	
Large lesions	0	0	0	0	
Vocal cord arytenoid					
Normal	48	50	48	50	1.000
Small lesions	0	0	0	0	
Large lesions	0	0	0	0	
Trachea redness					
Normal	47	47	29	41	0.006
Small lesions	1	3	15	6	
Large lesions	0	0	4	3	
Trachea edema					
Normal	48	50	46	49	0.536
Small lesions	0	0	2	1	
Large lesions	0	0	0	0	
Trachea hematoma					
Normal	44	50	13	33	0.002
Small lesions	1	0	7	4	
Large lesions	3	0	28	13	
Trachea bleeding					
Normal	47	50	44	48	0.656
Small lesions	0	0	4	2	
Large lesions	1	0	0	0	
Bronchial redness					
Normal	46	48	31	41	0.074
Small lesions	1	2	15	7	
Large lesions	1	0	2	2	

(*Continued*)

Table 1. (*Continued*)

	Preoperative		Postoperative		Difference between DLT and EZB Using Preoperative and Postoperative Difference (*P* Value)
	DLT (n = 48)	EZB (n = 50)	DLT (n = 48)	EZB (n = 50)	
Bronchial edema					
Normal	47	50	47	49	0.562
Small lesions	1	0	1	1	
Large lesions	0	0	0	0	
Bronchial hematoma					
Normal	45	47	26	38	0.007
Small lesions	2	3	7	9	
Large lesions	1	0	15	3	
Bronchial bleeding					
Normal	46	49	47	49	0.635
Small lesions	0	1	1	0	
Large lesions	2	0	0	0	
Main carina redness					
Normal	48	49	45	47	0.702
Small lesions	0	1	3	2	
Large lesions	0	0	0	1	
Main carina edema					
Normal	48	50	47	50	0.307
Small lesions	0	0	1	0	
Large lesions	0	0	0	0	
Main carina hematoma					
Normal	48	50	44	45	0.766
Small lesions	0	0	2	2	
Large lesions	0	0	2	3	
Main carina bleeding					
Normal	47	50	48	50	0.307
Small lesions	0	0	0	0	
Large lesions	1	0	0	0	

Vocal cord redness is redness of the vocal cords. Vocal cord erythema is redness of the mucosa with surrounding inflammatory swelling. Data are expressed as number. Classification: normal = 0; small lesions = 1; and large lesions = 2.
DLT = double-lumen tube; EZB = EZ-Blocker.

device was considered to be malpositioned when one of the following criteria was not observed: for DLT, the bronchial limb positioned in the left bronchus, unobstructed view of the tracheal carina (absence of bronchial cuff herniation), unobstructed view down the nonintubated bronchus, visualization of the proximal edge of the bronchial cuff below the tracheal carina, radiopaque line encircling the tube is seen above the tracheal carina, and unobstructed view of the left distal bronchial tree; for EZB, the extensions straddle the carina, the attachments of the extensions rests on the carina, unobstructed view down the carina (absence of balloon herniation), unobstructed view down the contralateral bronchus, and occlusion of all ostia of the mainstem bronchus after balloon inflation. Other study endpoints were the ease (1, excellent; 2, good; 3, average; and 4, poor) and duration (from visualization of vocal cords until initial positioning without bronchoscopy) of placement.

The Cormack and Lehane classification[14] was used to quantify the view at laryngoscopy (grade I, visualization of entire laryngeal aperture; grade II, visualization of posterior part of the laryngeal aperture; grade III, visualization of epiglottis only; and grade IV, not even the epiglottis is visible).

The ease (1, excellent; 2, good; 3, average; and 4, poor) and duration until correction of the malposition was also recorded. Once the devices were in the correct position, the cuffs or the balloons were successively insufflated under bronchoscopic view. The volume was recorded and the cuff pressure was measured with a handheld manometer (Endotest; Rüsch, Kernen, Germany) (upper limit, 130 cm H_20). The bronchial cuff or the balloons were then deflated. After the patient was turned to the lateral position, the pulmonologist assessed the correct position of the DLT or EZB again with bronchoscopy.

At least 3 min before initiation of OLV, the inspired oxygen concentration was increased to 100%. For a DLT, the bronchial cuff was insufflated and the appropriate channel was clamped and opened to air. For an EZB, the tube was disconnected from the ventilator for 60 s and then the correct balloon was insufflated with the same amount of air as determined previously. No further maneuvers were performed to facilitate lung collapse. During OLV, ventilator settings were adjusted to keep peak pressure below 25 cm H_2O and a positive end-expiratory pressure of 5 cm H_2O by increasing respiratory frequency and inspiratory/expiratory ratio and decreasing tidal volume. Where possible, arterial carbon dioxide tension was kept between 34 and 45 mmHg. The fraction of inspired oxygen was gradually reduced while aiming at an arterial saturation exceeding 95%. The surgeon, blinded to the technique, indicated when the collapse was halfway and scored the quality of lung collapse after 10 min and for the total period of OLV (1, excellent [complete collapse]; 2, good [some residual air]; 3, average [residual air interfering with surgical exposure]; and 4, poor [no collapse]).

At the end of surgery, the tubes were removed and a laryngeal mask was inserted. Again, the pulmonologist observed the airway for possible damage caused by the DLT or EZB with the bronchoscope. Injuries were classified, written on a chart, and stored on video.

Our second interest was the incidence of postoperative complaints of sore throat and hoarseness and of damage to laryngeal, tracheal, and bronchial structures. A blinded interrogator asked the patient postoperatively at the postanesthesia care unit and 24 h after the operation about sore throat (0, no sore throat; 1, mild [pain with deglutition]; and 2, moderate [pain constantly present and increasing with deglutition]) and postoperative hoarseness (0, no hoarseness; 1, noticed by patient; 2, noticed by observer; and 3, aphonia). Afterward, a pulmonologist (O.S. or E.H.), unaware of the device used, reviewed the videos before and after use of the devices for damage. Airway injuries were classified[6] as shown in table 1.

Statistical Analysis

A literature search for the incidence of malposition of left-side DLT[1–3,5,15] yielded a weighted mean incidence of malpositioning of the left-sided DLT(or proportion) of 55%. Using the Lehr formula,[16] we calculated that 50 patients in each group are required for the chi-square test to have an 80% chance of detecting a clinically important difference in malposition rate from 55% to 27% (a 50% decrease) at the two-side significance level of 5%.

Statistical analysis was performed using SPSS Statistics 18.0 (IBM Corp., Armonk, NY). Results were considered statistically significant for values of $P < 0.05$. Data are expressed as mean (SD) or median (range). The difference in proportion of initial malpositions is reported with 95% CI, and for analysis, the Fisher's exact test was used. Nonnormally divided data were analyzed using the Mann–Whitney rank sum test; otherwise, parametric independent Student *t* tests were used. Results based on ratings were tested using the Mann–Whitney rank sum test. Perioperative changes in airway injury were computed using the difference between postoperative and preoperative injuries, on which also a rank sum test was performed.

Results

Demographic data and sizes of the mainstem bronchi and trachea were not different between the groups (table 2). Type and side of the operation, duration of OLV, and sizes of the endotracheal tubes are listed in table 2. Figure 3 shows the number of patients at each phase of the trial. In one patient, a 41-French DLT could not pass through the vocal cords. In another patient, it was not possible to position a 35-French DLT in the left mainstem bronchus. These patients received an SLT and an EZB successfully and were excluded from further analysis.

The placement of an SLT and an EZB took a median of 25 s (range, 1.5–48 s), and placement of a DLT took a median of 13 s (range, 2.5–440 s) ($P = 0.001$). The placement of only an SLT was quicker than a DLT (table 3). The use of an SLT and an EZB is rated easier compared with a DLT ($P = 0.02$ and $P = 0.011$). Grade of intubation was equal in both groups ($P = 0.374$) (table 3).

Only 15% of DLTs and 26% of EZBs were placed correctly without the need for repositioning the device during bronchoscopic inspection. The 11% increase in initially correct positions (95% CI, −4 to 27%) when an EZB was used was not statistically significant ($P = 0.212$). In three cases in each group, a description of the type of malposition was not documented. A majority (n = 29) of DLTs were positioned too deep and a majority (n = 24) of EZBs were placed with both the extensions in the right mainstem bronchus. An extension of one EZB entered in the Murphy eye of the SLT. A DLT could be repositioned faster than an EZB (table 3). The number of correct positions and the duration of repositioning of the malpositioned devices after turning the patient during lateral thoracotomy and during one-lung ventilation were not different (table 3).

Cases where adhesions or other pulmonary findings were reported that could interfere with collapse of the lung were excluded when comparing both groups. The time to halfway collapse and the quality of collapse after 10 min and during the complete period of one-lung ventilation did not differ between the groups (table 4). A DLT needed to be repositioned four times during OLV (left side, n = 1; right side, n = 3); an EZB, four times (right side, n = 2; left side, n = 2). Volumes and pressures were 11 ml (range, 7–17 ml) and 120 cm H_2O (range, 65–130 cm H_2O) for the left balloon of the EZBs, and 14 ml (range, 8–17.5 ml) and 130 cm H_2O (range, 110–130 cm H_2O) for the right balloon.

More patients in the DLT group complained of sore throat at day 1 ($P = 0.046$). The incidence and severity of sore throat and hoarseness at day 1 and day 2 are listed in table 5. Data for three patients in each group were lost.

Table 1 represents the preoperative and postoperative findings of the bronchoscopic evaluation by the blinded pulmonologists. In three cases in each group, the videos were lost; however, for these cases, we retrieved the data from the record that was made directly after the bronchoscopic examination. There was a higher incidence of postoperative new

Table 2. Patient and Procedure Characteristics

	DLT (n = 50)	EZB (n = 50)	*P* Value
Age, yr	59 (13.6)	61 (13.3)	0.569
Male, n	35	36	
Female, n	15	14	
Weight, kg	80.0 (13.8)	77.0 (13.9)	0.294
Height, cm	172 (7.7)	174 (8.1)	0.332
Left main bronchus diameter, mm	13.5 (2.1)	13.4 (1.7)	0.774
Right main bronchus diameter, mm	13.6 (1.9)	13.9 (2.0)	0.348
Trachea diameter, mm	18.3 (2.6)	18.3 (3.2)	0.989
Type of operation, n			
Thoracotomy	27	25	
VATS	19	23	
Sternotomy	4	2	
Side of operation, n			
Left	27	29	
Right	22	20	
Both	1	1	
SLT, n			
7	NA	2	
8	NA	44	
9	NA	4	
DLT, n			
35	4*	NA	
37	11	NA	
39	12	NA	
41	23*	NA	

Data are expressed as mean (SD) or number.
* One DLT unable to place, patient excluded.
DLT = double-lumen tube; EZB = EZ-Blocker; NA = not applicable; SLT = single-lumen tube; VATS = video-assisted thoracoscopy.

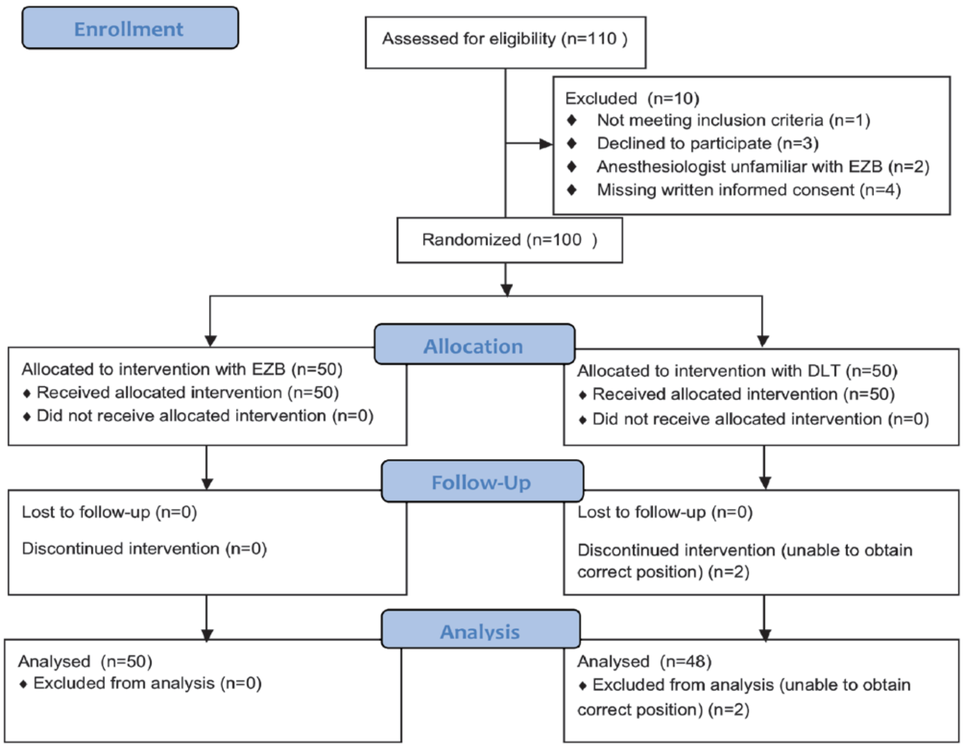

Fig. 3. Flowchart showing the number of patients at each phase of the trial. DLT = double-lumen tube; EZB = EZ-Blocker.

Table 3. Placement of Devices

	DLT	EZB		*P* Value	
		SLT	EZB	DLT *vs.* SLT	DLT *vs.* EZB
Time to place device, s				<0.0001	0.065
Median	13	5.0	19		
Range	2.5–440	0.5–27	1–40		
Intubation, n					
Grade 1	46	43		0.375	
Grade 2	3	5			
Grade 3	1	2			
Grade 4	0	0			
Ease of placing device, n					
Excellent	30	44	42	DLT *vs.* SLT 0.02	DLT *vs.* EZB 0.011
Good	10	3	8		
Average	7	3	0		
Poor	3	0	0		
Correct position, n/valid n					
After intubation	7/48*	13/50		0.212	
After repositioning patient	32/44	29/48		0.375	
During collapse	44/48	46/50		1.000	
Type of malposition after intubation, n					
Good position	7	13			
Deep	29	1			
Shallow	6	8			
Right	3	24			
Left	0	0			
Other	0	1			
Missing description	3	3			
Duration of repositioning, s					
After intubation					
Median	5.0	11.0			
Range	1.0–180.0	1.0–90.0		0.019	
Ease of repositioning device, n					
Excellent	36	26			
Good	3	8		0.065	
Average	2	3			
Poor	0*	0			
Duration of repositioning, s					
After repositioning patient					
Median	1.0	2.0			
Range	2.5–20.0	1.0–25.0		0.471	
During collapse					
Median	3.5	2.5			
Range	0.0–60.0	1.0–10.0		0.663	

Data are expressed as median (range) or number. Duration of placing a DLT *versus* an SLT plus an EZB, the Cormack and Lehane grade at intubation and the subjective rating of placement of the DLT and EZB (through SLT), and the prevalence and type of malpositioned devices and the duration and ease of repositioning of the devices are shown.

* Case(s) excluded from further analysis because of failed placement of a DLT.

DLT = double-lumen tube; EZB = EZ-Blocker; SLT = single-lumen tube.

or worsened airway injury such as tracheal hematoma and redness and bronchial hematoma in the DLT group. There was no difference in injuries at the vocal cord ($P = 0.390$) and main carina ($P = 0.777$), but there were more lesions at the tracheal ($P < 0.0001$) and bronchial ($P = 0.013$) levels in the DLT group. Ventilator settings (table 6) and arterial blood gas analysis (table 7) before and after one-lung ventilation were similar between the groups, except there was a lower peak airway pressure and a lower pH during OLV in the EZB group.

Table 4. Quality of Collapse

	DLT (n = 48)	EZB (n = 50)	*P* Value
Time to halfway collapse, s			
Median	120	90	0.751
Range	25–440	12–600	
Duration of OLV, min			
Median	63	83	0.248
Range	10–270	20–222	
Quality of collapse after 10 min, n			
Excellent	18	24	0.367
Good	23	18	
Average	1	3	
Poor	1	0	
NA	5	4	
Quality of collapse overall, n			
Excellent	30	35	0.804
Good	11	10	
Average	0	1	
Poor	0	0	
NA	5	4	

The time until halfway collapse and the subjective rating of the collapse by the operator after 10 min and overall are shown. Cases where adhesions or other pulmonary findings were reported that could interfere with collapse of the lung were excluded when comparing both groups. Data are expressed as median (range) or number.

DLT = double-lumen tube; EZB = EZ-Blocker; NA = not applicable; OLV = one-lung ventilation.

Table 5. Postoperative Complaints

	DLT	EZB	*P* Value
Total No.	45	47	
Sore throat on day 1			
No complaints or preexistent	34	44	0.046
Mild	5	2	
Moderate	5	1	
Severe	1	0	
Sore throat on day 2			
No complaints or preexistent	35	44	0.079
Mild	7	2	
Moderate	2	1	
Severe	1	0	
Hoarseness on day 1			
No hoarseness or preexistent	34	42	0.141
Noticed by patient	8	4	
Seen by observer	3	1	
Aphonia	0	0	
Hoarseness on day 2			
No hoarseness or preexistent	44	41	0.643
Noticed by patient	1	4	
Seen by observer	0	2	
Aphonia	0	0	

Rating of postoperative complaints: sore throat was graded as mild (pain with swallowing), moderate (pain present constant and increasing with swallowing), and severe (pain interfering with eating and require analgesic medication). Hoarseness was graded as follows: noticed by the patient, seen by the observer, or aphonia. Data were lost in three patients in each group. Data are expressed as number.

DLT = double-lumen tube; EZB = EZ-Blocker.

Discussion

The EZB and SLT were rated easier to place than the left-sided DLT. The time to initial placement of an SLT plus an EZB was longer than a DLT, mainly because placing an SLT and an EZB requires two separate actions. Placement of an SLT was faster than a DLT and there was no statistically significant difference in the time needed to place an EZB or a DLT. We believe that the differences are not clinically relevant except that some outliers above 30 s (n = 9) were observed in the DLT group. This indicates that placement of DLTs in most patients is easy but in a subset of patients is troublesome, an experience that is not unusual for the clinician. In two patients, it was not possible to place a left-sided DLT correctly, despite many attempts. A predictable technique, even if slightly slower, might be preferable. Other authors[4] have found that the time needed to place the devices was longer, but they included the time needed to control the position. A longer time to place and to check the position of the EZB[4] or other BBs[6,8,17] is a consistent finding in the literature.

The primary outcome is that, after blind insertion, only 15% of DLTs and 26% of EZBs were positioned correctly. The success rate is low in both groups. The 95% CI for the difference in success rate (–4% to 27%) shows that the difference is clinically irrelevant. Although a malposition was noted, it cannot be said that OLV when left uncorrected was not possible. Retrospectively, we cannot determine in which cases OLV might have been successful, because all malpositions (except one) were corrected. However, in both DLTs and EZBs, repositions of 1–3 cm were often needed. Successful OLV in such situations would seem unlikely. Other studies report the incidence of malpositioning of left-sided DLTs to range from 10–83% (weighted mean, 53%).[1–5,15] One effect of the higher than anticipated incidence of malposition of DLTs is that the number of patients enrolled is generous. Our rather stringent definition of device malposition may be responsible for the high rate of malpositions we report. Most malpositions with DLTs are attributable to positioning that is too deep. This is in agreement with other investigators.[2,3,15] In four cases, the left-sided DLT was positioned in the right mainstem bronchus. In one of these patients, it was not possible to correct the malposition and therefore this patient was excluded from further analysis. Other corrections were mostly rated easy (95% were excellent or good) and fast (median, 5 s; range, 1–180 s). Half of the EZBs entered the right mainstem bronchus with both extensions when inserted blindly. There are two possible reasons for this. First, if the distal end of the SLT is less than 4 cm above the carina, the extensions of the EZB

Table 6. Ventilator Settings before and during One-lung Ventilation

	DLT	EZB	*P* Value
Respiratory rate before OLV, breaths/min	12 (12–16)	12 (10–15)	0.151
Tidal volume before OLV, ml	475 (300–550)	475 (400–550)	0.916
Peak pressure before OLV, cm H_2O	19 (13–31)	20 (13–27)	0.393
PEEP before OLV, cm H_2O	0 (0 to10)	0 (0–8)	0.757
Respiratory rate during OLV, breaths/min	16 (12–22)	17 (12–26)	0.753
Tidal volume during OLV, ml	375 (280–550)	375 (270–525)	0.573
Peak airway during OLV, cm H_2O	25 (15–33)	22 (16–32)	0.024
PEEP during OLV, cm H_2O	4.5 (0–10)	4 (0–15)	0.438

Data are expressed as median (range).
DLT = double-lumen tube; EZB = EZ-Blocker; OLV = one-lung ventilation; PEEP = positive end-expiratory pressure.

cannot spread sufficiently and thus enter the right mainstem bronchus because it is positioned more in line with the trachea. Second, if the two extensions are advanced in a nonhorizontal plane in the supine patient, the extensions will more likely enter the right mainstem bronchus. Most malpositions could be corrected easily (92% were excellent or good) and fast (median, 11 s; range, 1–90 s) under bronchoscopic view, although it took more time compared with the correction of a DLT. As many experts in thoracic anesthesia advocate,[1,2,4,5,18–22] the high incidence of malpositions indicates that the use of bronchoscopic control is mandatory. If an EZB is initially placed under simultaneous bronchoscopic view, we expect correct placement in all patients, because all of our secondary corrections were easy, fast, and successful.

The number of DLTs or EZBs that dislodge after turning the patient to the lateral position were comparable (27% *vs.* 40%). The number of malpositions occurring during OLV was also comparable between DLTs and EZBs (8.3% and 8%). It had been shown that other BBs such as the Arnd blocker do not stay well in place after turning the patient into lateral position or during OLV.[8,17] Some investigators[8,23] claim that BBs perform better when positioned in the left mainstem bronchus *versus* the right. We found that the number of repositions of an EZB during OLV was small and divided equally between left and right. The balloon placed in the right mainstem bronchus had to be filled with 14 ml (median) to obtain occlusion, whereas on the left side 11 ml was sufficient. This corresponds to our measurements of the diameter of the right mainstem bronchus, which was 0.5 mm larger. The larger volume is also needed to close the aperture of the right upper lobe bronchus.

Unlike others,[8,17,20,23,24] we did not apply suction to DLTs or EZBs. Nevertheless, lung collapse was fast and rated excellent in the majority of patients with both devices. Some investigators[8,17] found slower collapse when using BBs. The use of preoxygenation and disconnecting the SLT or the appropriate leg of the DLT, as we did, allows rapid deflation.

Patients who had an EZB experienced less sore throat on day 1 compared with DLT patients. There was no difference between EZBs and DLTs in injury to vocal cords, which could have been an explanation for our finding.

Table 7. Arterial Blood Gas Analysis

	DLT	EZB	*P* Value
pH before OLV	7.35 (0.06)	7.34 (0.06)	0.804
P_{CO_2} before OLV, mmHg	48 (7.2)	48 (7.8)	0.796
P_{O_2} before OLV, mmHg	403 (161)	356 (149)	0.155
Saturation OLV collapse, %	99.7 (0.66)	99.4 (0.70)	0.117
Bicarbonate before OLV, mM	25.9 (2.15)	25.8 (2.24)	0.740
Base excess before OLV	−0.15 (2.43)	−0.17 (2.33)	0.967
pH during OLV	7.34 (0.05)	7.31 (0.06)	0.030
P_{CO_2} during OLV, mmHg	47 (7.1)	49 (6.7)	0.116
P_{O_2} during OLV, mmHg	183 (106)	182 (112)	0.972
Saturation during OLV, %	98.2 (2.58)	98.0 (2.26)	0.792
Bicarbonate during OLV, mM	25.4 (2.09)	25.4 (2.04)	0.884
Base excess during OLV	−0.62 (2.36)	−1.02 (2.77)	0.458

Blood gas analysis before and 10 min after lung collapse. Data are expressed as mean (SD).
DLT = double-lumen tube; EZB = EZ-Blocker; OLV = one-lung ventilation.

Other investigators also report a lower number of days with sore throat and less vocal cord injury when using an Arndt blocker compared with a DLT.[6] In a study comparing DLTs and EZBs,[4] there was no difference in the incidence of sore throat and hoarseness. The overall incidence of sore throat at day 1 (15%) was less than reported by others (33%[6] and 46%[4]).

We observed a high number (28 of 48) of tracheas with large hematomas in the DLT group. Typically, we could observe redness of the trachea on the point where the tip of the DLT touches the wall just below the vocal cords during insertion and then a trace of redness on the left side of the trachea caused by passing of the angled tip.

We expected two types of damage caused by the EZB. First, we could expect injury to the mainstem bronchus because of pressure exerted by the balloons. We recorded (median) volumes of 11 (left) and 14 ml (right) during slow injection of air into the balloons to create a seal of the bronchus. Pressures at that time are above 120 cm H_20. This is much above the recommended maximal intracuff pressure of 30 cm H_2O for endotracheal tubes.[25] However, Roscoe and colleagues[25] demonstrated that at intracuff volumes needed to create a seal to a positive pressure of 25 cm H_2O, the transmitted pressure are less than 30 cm H_2O. Thus, only a small fraction is transmitted to the bronchial wall. We found a low incidence (6% large hematoma) of bronchial hematoma in the EZB group, showing that the way we used high-volume balloons is safe. The incidence of large bronchial hematoma in the DLT group was much higher (31%). Another concern was the injury resulting from the pressure exerted by the EZB on the tracheal carina. Because the EZB is fixed securely between the main carina and the seal at the proximal end of the endotracheal tube, it stays well in place during OLV. We could not demonstrate that there was more injury to the carina when using an EZB compared with a DLT. Nevertheless, we recommend placing the EZB without excessive tension.

A limitation of the study is that we cannot completely exclude that postoperative injury to the airway might also be caused by the flexible bronchoscope itself. However, injury may have been minimized because experienced pulmonologists performed all bronchoscopic examinations. Apart from suffering sore throat at day 1, we cannot tell what the clinical relevance of the injury to the airways is. We did not follow the patients for more than 2 days and thus we are unaware of the long-term outcome.

Like all BBs, the EZB benefits from the fact that it is easier to insert in the presence of a difficult airway or a tracheostoma. If postoperative ventilation is required, there is no need to change the endotracheal tube, which is risky with swelling. There are situations were a DLT is preferred, such as pneumonectomy or bronchial sleeve resection, where the presence of the distal extension of a BB will disturb the surgical procedure or is at risk of being stuck in the sutures. Another situation where a DLT is preferred is absolute lung isolation, such as massive pus or blood collection in the distal bronchial tree and bronchopleural fistula with empyema, because of the ability to evacuate the material through the bronchial lumen. Furthermore, an EZB cannot be used for selective lobar blockade, which can be performed with other BBs.

In summary, an EZB is an easy and efficient device to allow OLV and causes less injury to the tracheal and bronchial mucosa. Also, the patient suffers less sore throat than when a DLT is used. The quality of lung deflation is equally good, and the EZB stays equally well in place during OLV. The use of bronchoscopic control of the position of the EZB after initial placement and after repositioning the patient is recommended, but this also applies for the DLT.

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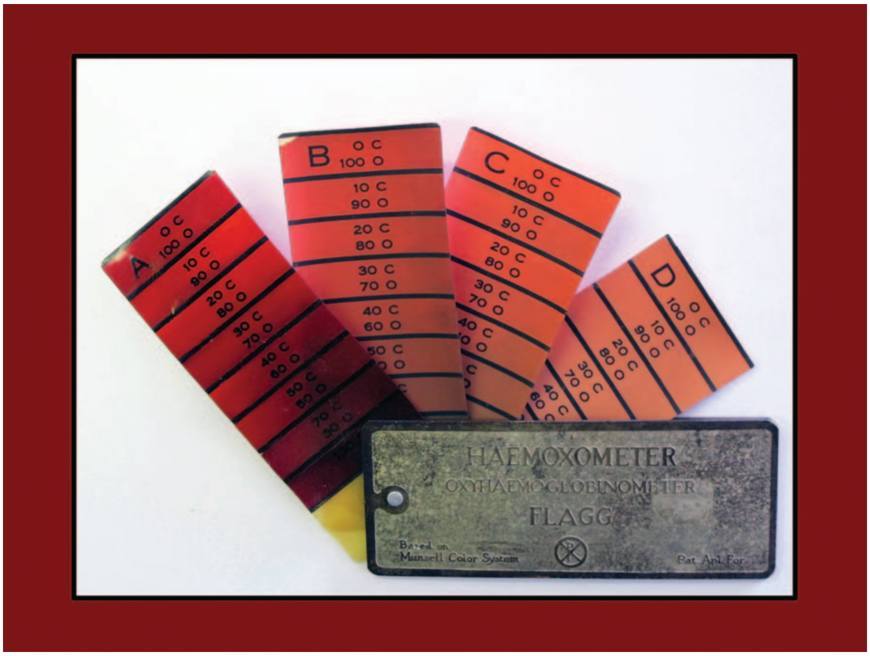
ANESTHESIOLOGY REFLECTIONS FROM THE WOOD LIBRARY-MUSEUM

P. J. Flagg's Haemoxometer



Using the Munsell color system, New York anesthesiologist Paluel J. Flagg designed a fanning index of color cards in the early 1920s for visually estimating just how oxygenated ("O") or cyanosed ("C") a patient was. According to his color cards (*from left to right above*) blood under different degrees of oxygen saturation was represented on Card A: blood "seen directly"; Card B: "average mucous membrane, or edge of ear of plethoric patient"; Card C: "pale mucous membrane or edge of ear of average patient"; and Card D: "pale edge of ear, or average finger nail." Note that Dr. Flagg did not consider many issues, including ambient lighting in the operating room or color blindness in the anesthesiologist. (Copyright © the American Society of Anesthesiologists, Inc.)

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