

Airway Injuries after One-lung Ventilation: A Comparison between Double-lumen Tube and Endobronchial Blocker

A Randomized, Prospective, Controlled Trial

Heike Knoll, M.D.,* Stephan Ziegeler, M.D.,* Jan-Uwe Schreiber, M.D.,* Heiko Buchinger, M.D.,* Patric Bialas, M.D.,* Kirill Semyonov, M.D.,* Thomas Graeter, M.D.,† Thomas Mencke, M.D.‡

Background: Vocal cord injuries, postoperative hoarseness, and sore throat are common complications after general anesthesia. One-lung ventilation can be achieved *via* two techniques: double-lumen endotracheal tube or endobronchial blocker such as the Arndt blocker. The current study was designed to assess the impact of these techniques for one-lung ventilation on the incidence and severity of postoperative hoarseness, vocal cord lesions, and sore throat.

Methods: In this prospective trial, 60 patients were randomly assigned to two groups. One-lung ventilation was achieved with either an endobronchial blocker (blocker group) or a double-lumen-tube (double-lumen group). Postoperative hoarseness and sore throat were assessed at 24, 48, and 72 h after surgery. Bronchial injuries and vocal cord lesions were examined by bronchoscopy immediately after surgery.

Results: In 56 included patients, postoperative hoarseness occurred significantly more frequently in the double-lumen group compared with the blocker group: 44% *versus* 17%, respectively ($P = 0.046$). Similar findings were observed for vocal cord lesions: 44% *versus* 17%, respectively ($P = 0.046$). The incidence of bronchial injuries was comparable between groups ($P = 0.540$). Cumulative number of days with hoarseness and sore throat were significantly increased in the double-lumen group compared with the blocker group ($P < 0.01$). No major complications such as bronchial ruptures were observed.

Conclusions: Clinicians should be aware of an increased incidence of minor airway injuries that may impair patient satisfaction when using a double-lumen tube instead of an endobronchial blocker for one-lung ventilation.

POSTOPERATIVE hoarseness, sore throat, and vocal cord injuries are common complications after general anesthesia.¹⁻⁶ The incidence of postoperative hoarseness is as frequent as 50% after short-term tracheal intubation.⁴ In the past, several risk factors for postoperative hoarseness and laryngeal injury have been identified, including demographic factors, quality of tracheal intubation, and technical factors such as endotracheal tube size.^{1,2,6,7-9}

One-lung ventilation during thoracotomy can be achieved *via* two basic techniques¹⁰⁻¹²: (1) use of a double-lumen endotracheal tube (DLT) consisting of an endotracheal and an endobronchial lumen allowing independent single-lung ventilation¹³; or (2) use of an endobronchial blocker such as the Arndt blocker, which allows lung collapse distal to the occlusion.^{11,14} It has been recently demonstrated that DLT and endobronchial blocker are similar in their efficacy to achieve lung isolation for elective thoracic surgery.¹¹ No data are available yet about the influence of the chosen technique on postoperative hoarseness, vocal cord injuries, sore throat, and bronchial injuries. Published data of Stout *et al.*⁷ imply that the incidence of postoperative hoarseness and vocal cord injury might be directly correlated with size of the used endotracheal tube. We hypothesized that using a bronchial blocker to achieve one-lung ventilation may result in a lower incidence of clinically relevant laryngeal and bronchial morbidity after open thoracotomy compared with a control group intubated with a DLT. In addition, vocal cord lesions and bronchial injuries were assessed by bronchoscopy and flexible laryngoscopy postoperatively.

Materials and Methods

Patients

After obtaining approval from the ethics committee (Ärztchamber des Saarlandes, Saarbrücken, Germany) and written informed consent, we studied 60 adult patients aged 18-75 yr with American Society of Anesthesiologists physical status I-III. All patients underwent thoracic surgical procedures (open pulmonary resection) requiring one-lung ventilation. Patients with preexisting hoarseness or sore throat were not included. Study exclusion criteria included a duration of surgery greater than 6 h, obesity, pregnancy, known difficult tracheal intubation, and patients suspected to have a difficult airway, *i.e.*, Mallampati airway class score 3 or 4, and mouth opening less than 3.5 cm. Patients with difficult intubation conditions, *i.e.*, Cormack and Lehane¹⁵ score of 3 or 4, were excluded after induction of anesthesia.

Induction and Maintenance of Anesthesia

Patients were randomly assigned to two groups of 30 patients each, *via* random number draws, to receive

This article is featured in "This Month in Anesthesiology."
Please see this issue of ANESTHESIOLOGY, page 5A.

* Staff Anesthesiologist, Department of Anesthesiology and Critical Care Medicine, † Instructor, Department of Thoracic and Cardiovascular Surgery, University Hospital of the Saarland. ‡ Staff Anesthesiologist, Department of Anesthesiology and Intensive Care Medicine, University of Rostock, Rostock, Germany.

Received from the Department of Anesthesiology and Critical Care Medicine, University Hospital of the Saarland, Homburg, Germany. Submitted for publication January 13, 2006. Accepted for publication May 3, 2006. Support was provided solely from institutional and/or departmental sources.

Address correspondence to Dr. Mencke: Department of Anesthesiology and Intensive Care Medicine, University of Rostock, Schillingallee 35, 18057 Rostock, Germany. thomas.mencke@uni-rostock.de. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

either the wire-guided endobronchial blocker (blocker group) or a DLT (double-lumen group).

After arrival of the patients in the operating room, standard monitoring was used. All patients received a thoracic epidural catheter for control of postoperative pain. Induction of anesthesia was standardized for both groups as follows: At time 0, 3.0 $\mu\text{g}/\text{kg}$ fentanyl was injected; 3 min later, anesthesia was induced with 3.0 mg/kg propofol. Anesthesia was maintained with 0.25–0.5 $\mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ remifentanyl and 4–6 $\text{mg} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$ propofol. Ventilation was controlled with oxygen (100%) *via* a facemask. Two minutes later, 0.5 mg/kg atracurium was injected over a period of 10 s. Tracheal intubation was performed exactly 3 min later. Surgeons were absent from the operating room during tube placement and were blinded to randomization. Vital signs, *i.e.*, heart rate and mean arterial blood pressure, were recorded 30 s after the propofol administration, before tracheal intubation, and 2 min after tracheal intubation.

In the blocker group, tracheal intubation was performed with a single-lumen endotracheal tube (Magill, Lo-Contour Murphy Tracheal Tube; Mallinckrodt, Athlone, Ireland). Tube size was standardized regarding patients' sex. In men, an 8.5-mm ID was used, and in women, a 7.5-mm ID was used. Afterward, the wire-guided endobronchial blocker (9 French; spherical-shaped balloon with inflation volume of 4.0–8.0 ml, Arndt blocker; Cook Critical Care, Bloomington, IN) was bronchoscopically guided into either the right (for right pulmonary resection) or left mainstem bronchus (for left pulmonary resection).

In the double-lumen group, after passing the vocal cords the DLT was rotated 90° toward the left (Bronchocath, left-sided; Rüschi, Kern, Germany) or right (Bronchocath, right-sided; Rüschi) and advanced until slight resistance occurred. If this technique failed, the DLT was guided into position *via* the bronchoscope. Tube size (35, 37, 39, or 41 French) was determined by measuring the width of the tracheal diameter in millimeters from the preoperative chest radiograph.¹⁶ Accuracy of the DLT or blocker placement was assessed by flexible fiberoptic bronchoscopy.

Patients were carefully positioned for surgery and the head was fixed. After the patient was turned to the lateral position, the correct position of the DLT or blocker was assessed again by bronchoscopy. During one-lung ventilation, inspired oxygen concentration was increased to 100%.

Twenty minutes before the expected end of surgery, all patients received 10 μg sufentanil and 10.0 ml bupivacaine, 0.25%, *via* the epidural catheter. After completing surgery and bronchoscopic examination, all patients were carefully extubated. For postoperative pain therapy, sufentanil and 0.25% bupivacaine were given by request *via* the epidural catheter. Paracetamol and pir-

tramide, 0.05 mg/kg intravenous, was given when analgesia was inappropriate.

Assessment of Intubating Conditions and Intubating Variables

Tracheal intubation was performed by the same experienced anesthesiologist. The intubating score was evaluated on the basis of the consensus conference on Good Clinical Research Practice in Pharmacodynamic Studies of Neuromuscular Blocking Agents.¹⁷

In addition, the following intubating variables were recorded: glottic exposure as defined by Cormack and Lehane; the number of intubation attempts (n) and corrections of positioning (n); time for intubation (s), defined as the time from the beginning of laryngoscopy until successful intubation; and time for positioning (s), defined as the time of bronchoscopy for verification of the correct position of the blocker or DLT.

The following factors were standardized for all patients: use of a stylet for single-lumen tubes and DLTs, use of 2% lidocaine gel, and intracuff pressure less than 30 mmHg (measured with a noninvasive manometer).

Assessment of Surgical Variables

Collapse of the lung was assessed as follows¹¹: 1 = spontaneous; 2 = assisted with suction; 3 = manual. The thoracic surgeon blinded to the group assignment rated the conditions of surgery as follows¹¹: 1 = excellent (complete collapse with perfect surgical exposure); 2 = fair (total collapse, but the lung still has residual air); 3 = poor (no collapse, or if there is partial collapse with interference in surgical exposure).

Assessment of Postoperative Hoarseness, Sore Throat, and Airway Injuries

Immediately after completion of surgery, all patients underwent a bronchoscopic examination on bronchial lesions before emerging from anesthesia. After successful extubation, 30 mg topical lidocaine spray, 2%, was administered nasally, and flexible laryngoscopy was performed to assess vocal cord injuries. Findings from bronchoscopy and laryngoscopy were recorded by videotape and demonstrated to an experienced ear, nose, and throat specialist who was not aware of the group assignment. Airway injuries were classified as shown on table 1.^{6,8,18}

Postoperative hoarseness was defined as an acoustic quality that was different than the previous voice quality of the patient.¹⁹ Sore throat was defined as continuous throat pain.¹ An investigator blinded to the group assignment of the patients asked the patients specific questions regarding postoperative hoarseness, and sore throat immediately after emergence from anesthesia and on days 1, 2, and 3 after surgery^{8,20} (appendix). A daily follow-up examination was performed until complete resolution.

Table 1. Classification of Airway Injuries

Type	Classification	Definition
Bronchial injuries	Redness	
	Edema	Swollen mucosa
	Hematoma	Bleeding into mucosa
Vocal cord injuries	Thickening of the vocal cords	Localized swelling at the vocal process of the arytenoids cartilage
	Redness	
	Edema	Swollen mucosa at the vocal folds
	Erythema	Redness of the mucosa with surrounding inflammatory swelling
	Hematoma	Bleeding into vocal cord
	Granuloma	Granulation tissue remains as a chronic, localized, rounded tissue

Statistical Analysis

Statistical analysis was performed using BiAS 8.1-2005 for Windows (Epsilon-Verlag, Hochheim, Germany). The required number of patients for the study groups was calculated in expectation of an incidence of postoperative hoarseness of 16%⁶ in the blocker group and a 40% increase of the absolute risk in the double-lumen group. For an 80% power and an α of 0.05, 52 patients (26 patients in each group) were needed. To compensate for possible dropouts, we enrolled 60 patients, *i.e.*, 30 patients for each group. Results were considered statistically significant when P was less than 0.05. Data are expressed as mean \pm SD or median (range). Chi-square test or Fisher exact test, one-way analysis of variance for parametric data, and Kruskal-Wallis test for nonparametric data were used as appropriate. Numbers needed to harm (NNHs) were calculated.²¹ A positive NNH indicated how many patients had to be exposed to the intervention (*i.e.*, DLT) to produce one particular event (*i.e.*, postoperative hoarseness or airway injury) in one patient, who would not have had this event had he or she received a single-lumen tube combined with an endobronchial blocker for one-lung ventilation. An NNH between 1 and 5 was considered a clinically relevant risk.²²

Results

Sixty patients were enrolled in this study—30 patients in each group. Of these 60 patients, 4 patients were

excluded from analysis because of a Cormack grade of 3 or greater (1 in the blocker group and 3 in the double-lumen group). Therefore, incidence and severity of airway injuries, postoperative hoarseness, and sore throat were investigated in the remaining 56 patients—29 in the blocker group and 27 in the double-lumen group. There were no significant differences between the two groups with respect to demographic data and duration of anesthesia and surgery (table 2). A significant difference was found in the incidence of smoking ($P = 0.046$; table 2). The surgical sides of thoracotomy, *i.e.*, right or left side, were comparable between groups ($P = 0.611$). In addition, there were no significant differences in hemodynamic values between the two groups.

Tracheal intubation was successful in all patients of both groups. Number of attempts and Cormack grades did not differ significantly between the study groups. Time for positioning and number of corrections of positioning of the blocker or DLT did not differ significantly (table 3). Moreover, intubating conditions were comparable between groups (not significant).

Quality of lung collapse was significantly better in patients with a DLT. Excellent or fair conditions for surgery were found in 22 patients in the blocker group *versus* 27 patients in the double-lumen group ($P = 0.01$). In patients with an endobronchial blocker, no significant relation between time of deflation and quality of collapse was found ($P = 0.09$).

Bronchoscopic examination of the bronchus was per-

Table 2. Demographic Data and Duration of Surgery and Anesthesia

	Blocker (n = 29)	Double Lumen (n = 27)	P Value
Age, yr	62.8 \pm 8.5	60.4 \pm 8.5	0.286
Weight, kg	75.4 \pm 10.8	78.5 \pm 14.5	0.377
Height, cm	168.6 \pm 10.3	168.4 \pm 7.9	0.931
Sex, male/female	17/12	17/10	0.740
Smoking	5	12	0.046
Reflux	1	0	1.000
ASA physical status	II (I–III)	II (II–III)	0.454
Side, left/right	17/12	14/13	0.611
Duration of surgery, min	110 (60–200)	120 (40–240)	0.379
Duration of anesthesia, min	170 (95–245)	180 (105–310)	0.391

Values are mean \pm SD, numbers, or median and range (American Society of Anesthesiologists [ASA] physical status, duration of surgery, and duration of anesthesia).

Table 3. Intubating Variables and Intubating Conditions

	Blocker (n = 29)	Double Lumen (n = 27)	P Value
Intubating variables			
Cormack grades	1 (1–2)	1 (1–2)	0.208
Time for intubation, s	15 (4–150)	25 (5–90)	0.003
Attempts, n	1 (1–2)	1 (1–2)	0.468
Time for positioning, s	90 (12–640)	60 (15–480)	0.081
Correction of positioning, n	1 (0–3)	0 (0–2)	0.349
Surgical variables			
Time for evacuation, min	8 (1–18)	7 (1–20)	0.408
Time for OLV, min	70 (20–162)	73 (25–185)	0.413
Collapse of lung*	2 (1–3)	1 (1–3)	< 0.001
Conditions for surgery†	2 (1–3)	1 (1–2)	< 0.001

Values are median (range).

* Collapse of the lung¹¹: 1 = spontaneous; 2 = assisted with suction; 3 = manual. † Conditions of surgery¹¹: 1 = excellent (complete collapse with perfect surgical exposure); 2 = fair (total collapse, but the lung still has residual air); 3 = poor (no collapse, or if there is partial collapse with interference in surgical exposure).

OLV = one-lung ventilation.

formed in all patients after positioning of the DLT or blocker and immediately before extubation (table 4). The overall incidence (DLT and endobronchial blocker combined) of bronchial injuries was 25% (14 patients). The incidence of bronchial injuries did not differ significantly between the blocker and double-lumen groups: 6 *versus* 8 patients, respectively ($P = 0.440$). The bronchoscopic findings are shown in table 4. Endoscopic examination of the larynx was performed in all patients immediately after extubation. The overall incidence of vocal cord injuries was 30% (17 patients). Vocal cord injuries occurred significantly more frequently in the double-lumen group compared with the blocker group: 12 patients (44%) *versus* 5 patients (17%), respectively ($P = 0.046$; table 4). The NNH to produce one patient with vocal cord injuries by using the DLT compared with the blocker was 4 (confidence interval, 2.0–25.3). The majority of the vocal cord injuries were redness (8 patients) and edema (8 patients). In the double-lumen group, one hematoma was noted.

None of the patients needed to be reintubated due to

Table 4. Incidence and Bronchoscopic Findings of Bronchus Injuries and Vocal Cord Injuries

	Blocker (n = 29)	Double Lumen (n = 27)	P Value
Bronchus injuries			
Patients*	6	8	0.540
Morphology			
Redness	6	5	1.000
Edema	0	3	0.237
Hematoma	0	2	0.492
Vocal cord injuries			
Patients*	5	12	0.046
Morphology			
Redness	2	6	0.137
Edema	3	5	0.462
Hematoma	0	1	1.000

Values are numbers (n).

* Number of patients with bronchus injuries or vocal cord injuries.

postoperative respiratory failure. Moreover, a prolonged stay in the intensive care unit was not indicated in any patient.

The overall incidence of postoperative hoarseness was 30% (17 patients). Postoperative hoarseness occurred significantly more frequently in the double-lumen group compared with the blocker group: 12 patients (44%) *versus* 5 patients (17%), respectively ($P = 0.046$; table 5). The NNH to produce one patient with postoperative hoarseness by using the DLT compared with using the blocker was 4 (confidence interval, 2.0–25.3). Follow-up examination revealed that no patient had postoperative hoarseness more than 3 days (table 5). Therefore, no stroboscopic examination of the larynx was performed in any patient. The severity of hoarseness did not differ significantly between both study groups. However, the cumulative number of days with postoperative hoarseness over the entire study population was significantly increased in the double-lumen group compared with the blocker group: 22 *versus* 8, respectively ($P = 0.006$; table 5).

The overall incidence of sore throat was 41% (23 patients). Sore throat did not differ significantly between groups: 14 patients (48%) *versus* 9 patients (31%), respectively ($P = 0.174$; table 5). In addition, the severity of sore throat did not differ significantly between study groups. Sore throat was limited in both groups to the postoperative period up to 72 h after surgery. However, the cumulative number of days with sore throat over all patients was significantly increased in the double-lumen group compared with the blocker group: 35 *versus* 18, respectively ($P = 0.007$; table 5).

Discussion

There had been no prospective investigation before that systematically evaluated the possible role of the

Table 5. Incidence of Postoperative Hoarseness and Sore Throat

	Postoperative Hoarseness			Sore Throat		
	Blocker (n = 29)	DLT (n = 27)	P Value	Blocker (n = 29)	DLT (n = 27)	P Value
PACU	2	6	0.137	6	9	0.369
At 24 h	3	8	0.096	7	12	0.159
At 48 h	3	5	0.462	4	10	0.065
At 72 h	1	3	0.612	1	5	0.195
> 72 h	0	0	—	0	0	—
Days*	8	22	0.006	18	35	0.007
Patients†	5	12	0.041	9	14	0.174

Values are numbers of patients (n).

* Days = number of days with postoperative hoarseness (PH) or sore throat (ST). † Number of patients with PH or ST.

DLT = double-lumen tube; PACU = postanesthesia care unit.

different techniques to achieve one-lung ventilation on the incidence and severity of laryngeal injury. Therefore, the current study was designed to assess the impact of the one-lung ventilation technique on the incidence and severity of airway injuries and laryngeal morbidity.

The current study demonstrated that incidence of postoperative hoarseness and number of days with hoarseness and sore throat were significantly decreased in the blocker group compared with the double-lumen group. Moreover, the blocker technique was associated with a decreased incidence of vocal cord injuries.

Many factors contribute to laryngeal intubation trauma.⁸ Several risk factors for postoperative hoarseness and vocal cord injuries have been identified, including demographic factors such as sex,² gastroesophageal reflux,⁹ intubating conditions,⁶ duration of surgery,²³ type of surgery,²⁴ and technical factors such as endotracheal tube size.⁷ Risk factors known to contribute to postoperative hoarseness and vocal cord injuries were controlled in the current study. Intubation conditions including subcomponents such as vocal cords and reaction to tube insertion or cuff inflation were comparable in all patients. However, we consequently excluded patients with a laryngoscopic view graded 3 or 4 according to Cormack and Lehane to avoid any variability in results due to a possibly difficult airway. Moreover, it has been widely accepted that using a bronchial blocker for patients with difficult airways should be the method of choice. The patient population was uniform with respect to the patient characteristics (except smoking), as well as to the type and duration of anesthesia and surgery (table 2). The incidence of smoking was significantly higher in the double-lumen group compared with the blocker group ($P = 0.046$). Smoking has been described as a risk factor for hoarseness.⁸ To minimize any influence of preexisting hoarseness, those patients were not included in this trial. Moreover, no significant differences in postoperative hoarseness or vocal cord injuries in smokers *versus* nonsmokers were found.

Double-lumen endotracheal tubes are the most widely used devices for lung separation and one-lung ventila-

tion.^{12,13} In 1999, the Arndt blocker was introduced and has been demonstrated as an alternative technique that produces comparable surgical conditions in thoracotomy.^{11,14} In the current trial, quality of lung collapse and surgical exposure differed significantly between the two techniques. This result stands in contrast to previous findings of other authors and might be explained by a relatively short time for deflation in our study groups. However, surgery in each patient was finished successfully without any further intervention or delay in surgical progress.

There is a large variation in the reported incidence (3–50%) of hoarseness immediately after short-term tracheal intubation.^{2–4,6,25} Tracheal intubation with 0.5 mg/kg atracurium (same dosage as in our study) 3 min after induction of anesthesia (same waiting time as in our current study) was associated with an infrequent incidence of postoperative hoarseness of 16%.⁶ In our current study, however, the overall incidence of postoperative hoarseness was 30% but reached 44% in the double-lumen group (table 5). The reasons for the significantly increased incidence of postoperative hoarseness in the double-lumen group compared with the blocker group might be best explained as follows.

First, DLTs are tubes with a curved endobronchial lumen, which may come in contact with the vocal cords during insertion and cause hoarseness. Second, the DLTs used in the current study ranged between 37 and 41 French; the single-lumen tubes that were used in the blocker group (men: ID = 8.5 mm; women: ID = 7.5 mm) correspond to approximately 32–36 French. Stout *et al.*⁷ demonstrated that the incidence and severity of postoperative hoarseness and sore throat was directly correlated to the size of the endotracheal tubes. Therefore, this may be the main risk factor for laryngeal injuries and postoperative hoarseness. Third, the trauma causing laryngeal injury can occur not only during induction of anesthesia and during surgery, but also during tracheal extubation.⁸ Therefore, presumably, another injury of the vocal cords followed by postoperative hoarseness took place during extubation by the curved DLT.

Intubation-related laryngeal injuries were found to be present in up to 27% of patients with the use of neuromuscular blocking agents for tracheal intubation^{3,6,18,25,26} and reached 44% in patients with an induction technique without neuromuscular blockers.⁶ In our current study, the overall incidence was 30%. However, all patients were examined by flexible laryngoscopy after surgery, not by laryngostroboscopy, *i.e.*, the diagnostic tool used was not as sensitive as it was in the previous studies of our group.^{6,25} Because of technical limitations, no opportunity for a laryngostroboscopy during the first 72 h after anesthesia was given in this study. Presumably, the majority of the minor injuries of the vocal folds such as thickening of the vocal folds, which had an incidence up to 86%,²⁵ were not determined by flexible laryngoscopy after surgery. In addition, we cannot completely exclude that vocal cord injuries in single patients might have existed preoperatively. However, the main goal of our study was to evaluate clinically relevant postoperative hoarseness and sore throat that might impair patient satisfaction.

No patient had postoperative hoarseness or sore throat on the fourth day after surgery; therefore, no patient was examined by laryngostroboscopy. In general, longer lasting postoperative hoarseness does not seem to be a frequent complication. In a previous study, Jones *et al.*²⁷ reported 5 of 167 patients who had postoperative hoarseness for more than 5 days after anesthesia. The lack of patients with longer lasting sore throat or postoperative hoarseness might be best explained by the limited size of our study.

Vocal fold paralysis due to laryngeal nerve damage is a known complication after thoracic surgery with a suspected incidence from 4 to 31%.²⁸ It cannot be completely excluded that patients of the current trial had temporal nerve damage. However, type of surgery was comparable between both groups.

The bronchoscopic examination before extubation allowed assessing bronchus injuries as well. There are no prospective data available about bronchial injuries after one-lung ventilation with a blocker or DLT. The incidence was 25% and comparable between the double-lumen group and blocker group (not significant; table 4). The incidence of injuries at the level of the mainstem bronchus is similar to the observed incidence of injuries at the larynx. Presumably, the pathogenesis is similar to that for vocal cord lesions. When the pressure of the cuff or the tube itself exceeds capillary pressure in the mucosa of the bronchus, mucosal ischemia causes inflammation, congestion, and edema within the first few hours.⁸ We measured the cuff pressure but suppose that it might not always represent the actual pressure at the mucosa of the bronchus. Other risk factors for vocal cord and bronchial injuries might be friction and physical contact of the tube with laryngeal and bronchial structures. In addition, movement and pressure during

surgical manipulations, pressure during lateral position, and movements of the DLT during bronchoscopy may influence the incidence of laryngeal and bronchial morbidity.

The reported incidence of sore throat varies between 14.4 and 50%.^{1,3,4,7,25} In the current study, the incidence of sore throat was 41%. There was no significant difference in the incidence between the two study groups. However, the cumulative number of days with sore throat was significantly increased in the double-lumen group compared with the blocker group. The reason for the higher count of days with sore throat might be the same as for postoperative hoarseness, *i.e.*, the increased size of the DLT and the curved shape.¹ In addition, we cannot exclude that the higher incidence of smokers in the double-lumen group may have influenced this finding.

The results of the current trial show that the risk for airway complications may increase when using a DLT instead of a bronchial blocker to achieve one-lung ventilation. The calculated NNH of 4 for postoperative hoarseness reflects this issue. Most of the observed airway lesions were minor, and no patient showed clinical signs of postoperative hoarseness or sore throat after the third postoperative day. However, hoarseness and sore throat may cause discomfort and may impair patient satisfaction. None of the included patients had rare major complications such as bronchial rupture or vocal cord paralysis. It remains unclear whether the use of a bronchial blocker may prevent serious complications such as bronchial rupture.

In conclusion, clinicians should be aware of the increased risk of postoperative hoarseness when using a DLT instead of a bronchial blocker. It is recommended to inform patients about this risk if they are scheduled for one-lung ventilation with a DLT.

The authors thank Mathias Echtermach, M.D. (Staff, Department of Otorhinolaryngology, University Hospital of the Saarland, Homburg, Germany), for his support during this study.

Appendix: Assessment of Postoperative Hoarseness (PH) and Sore Throat (ST)

A. Do you have any hoarseness?

If the answer was no, PH was graded 0 = no hoarseness;

if the answer was yes, PH was graded 1-3 as follows⁷:

- 1 = noticed by patient,
- 2 = obvious to observer,
- 3 = aphonia.

B. Do you have any sore throat?

If the answer was no, ST was graded 0 = no sore throat;

if the answer was yes, ST was graded 1-3 as follows²⁰:

- 1 = mild (pain with deglutition),
- 2 = moderate (pain present constantly and increasing with deglutition),
- 3 = severe (pain interfering with eating and requiring analgesic medication).

References

1. McHardy FE, Chung F: Postoperative sore throat: Cause, prevention and treatment. *Anaesthesia* 1999; 54:444-53
2. Jones MW, Catling S, Evans E, Green DH, Green JR: Hoarseness after tracheal intubation. *Anaesthesia* 1992; 47:213-6
3. Oczeni W, Krenn H, Dahaba AA, Binder M, El-Shahawi-Kienzl I, Kohout S, Schwarz S, Fitzgerald RD: Complications following the use of the Combitube, tracheal tube and laryngeal mask airway. *Anaesthesia* 1999; 54:1161-5
4. Christensen AM, Willemoes-Larsen H, Lundby L, Jakobsen KB: Postoperative throat complaints after tracheal intubation. *Br J Anaesth* 1994; 73:786-7
5. Higgins PP, Chung F, Mezei G: Postoperative sore throat after ambulatory surgery. *Br J Anaesth* 2002; 88:582-4
6. Mencke T, Echternach M, Kleinschmidt S, Lux P, Barth V, Plinkert PK, Fuchs-Buder T: Laryngeal morbidity and quality of tracheal intubation: A randomized controlled trial. *ANESTHESIOLOGY* 2003; 98:1049-56
7. Stout DM, Bishop MJ, Dwersteg JF, Cullen BF: Correlation of endotracheal tube size with sore throat and hoarseness following general anesthesia. *ANESTHESIOLOGY* 1987; 67:419-21
8. Benjamin B: Laryngeal trauma from intubation: endoscopic evaluation and classification. *Otolaryngology & Head & Neck Surgery*. Edited by Cummings CW, Frederickson JM. St. Louis, Mosby, 2001, pp 2013-35
9. Smit CF, Mathus-Vliegen LMH, Devriese PP, Schouwenburg PF, Kupperman D: Diagnosis and consequences of gastropharyngeal reflux. *Clin Otolaryngol* 2000; 25:440-55
10. Campos JH, Reasoner DK, Moyers JR: Comparison of a modified double-lumen endotracheal tube with a single-lumen tube with enclosed bronchial blocker. *Anesth Analg* 1996; 83:1268-72
11. Campos JH, Kernstine KH: A comparison of a left-sided Bronchocath[®] with the torque control blocker Univent and the wire-guided blocker. *Anesth Analg* 2003; 96:283-9
12. Cohen E: Management of one-lung ventilation. *Anesthesiol Clin North Am* 2001; 19:475-95
13. Benumof JL, Partridge BL, Salvatierra C, Keating J: Margin of safety in positioning modern double-lumen endotracheal tubes. *ANESTHESIOLOGY* 1987; 67:729-38
14. Arndt GA, Kranner PW, Rusy DA, Love R: Single-lung ventilation in a critically ill patient using a fiberoptically directed wire-guided endobronchial blocker. *ANESTHESIOLOGY* 1999; 90:1484-6
15. Cormack RS, Lehane J: Difficult tracheal intubation in obstetrics. *Anaesthesia* 1984; 39:1105-11
16. Brodsky JB, Macario A, Mark JBD: Tracheal diameter predicts double-lumen tube size: A method for selecting left double-lumen tubes. *Anesth Analg* 1996; 82:861-4
17. Viby-Mogensen J, Engbaek J, Eriksson LI, Gramstad L, Jensen E, Jensen FS, Koscielniak-Nielsen Z, Skovgaard LT, Ostergaard D: Good clinical research practice (GCRP) in pharmacodynamic studies of neuromuscular blocking agents. *Acta Anaesthesiol Scand* 1996; 40:59-74
18. Peppard SB, Dickens JH: Laryngeal injury following short-term intubation. *Ann Otol Rhinol Laryngol* 1983; 92:327-30
19. Woo P, Colton R, Casper J, Brewer D: Diagnostic value of stroboscopic examination in hoarse patients. *J Voice* 1991; 5:231-8
20. Capon LM, Bruce DL, Patel KP, Turndorf H: Succinylcholine-induced postoperative sore throat. *ANESTHESIOLOGY* 1983; 59:202-6
21. Laupacis A, Sackett DL, Roberts RS: An assessment of clinically useful measures of the consequences of treatment. *N Engl J Med* 1988; 318:1728-33
22. Tramèr MR, Fuchs-Buder T: Omitting antagonism of neuromuscular block: Effect on postoperative nausea and vomiting and risk of residual paralysis: A systematic review. *Br J Anaesth* 1999; 82:379-86
23. Lesser THJ, Lesser PJA: Laryngeal trauma *versus* length of intubation. *J Laryngol Otol* 1987; 101:1165-7
24. Inada T, Fujise K, Shingu K: Hoarseness after cardiac surgery. *J Cardiovasc Surg* 1998; 39:455-9
25. Mencke T, Echternach M, Plinkert PK, Johann U, Afan N, Rensing H, Noeldge-Schomburg G, Knoll H, Larsen R: Does the timing of tracheal intubation based on neuromuscular monitoring decrease laryngeal injury? A randomized, prospective, controlled trial. *Anesth Analg* 2006; 102:306-12
26. Kambic V, Radsel Z: Intubation lesions of the larynx. *Br J Anaesth* 1978; 50:587-90
27. Jones MW, Catling S, Evans E, Green DH, Green JR: Hoarseness after tracheal intubation. *Anaesthesia* 1992; 47:213-6
28. Schneider B, Schickinger-Fischer B, Zumtobel M, Mancusi G, Bigenzahn W, Klepetko W, End A: Concept for diagnosis and therapy of unilateral recurrent laryngeal nerve paralysis following thoracic surgery. *Thorac Cardiovasc Surg* 2003; 51:327-31