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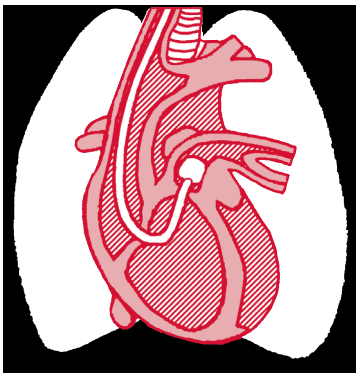

CASE CONFERENCE

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Tracheobronchial Rupture After Double-Lumen Endotracheal Intubation

Hong Liu, MD,* Jonathan S. Jahr, MD,† Erin Sullivan, MD,‡ and Paul F. Waters, MD, FACS,§

Tracheobronchial ruptures resulting from endotracheal intubation are rare but may be life-threatening.[1] Immediate recognition and adequate treatment are very important in managing this potentially fatal situation. Diagnosis of such conditions is difficult and thus a high level of suspicion must be maintained when presented with the classic symptoms of mediastinal and subcutaneous emphysema and respiratory distress.[2] The authors report a case of tracheobronchial rupture after double-lumen endobronchial intubation and its diagnosis and treatment.

CASE REPORT*†

A 76-year-old white woman with a history of lung cancer was scheduled for left lower lobectomy in November 2000. The patient was 142-cm tall and weighed 39.2 kg; her medical history included idiopathic hypertrophic subaortic stenosis, coronary artery disease with a myocardial infarction in 1998, hypertension, cardiomyopathy, cerebrovascular disease with 2 strokes, peripheral vascular disease, hypercholesterolemia, hyperparathyroidism, chronic obstructive pulmonary disease, breast cancer with lung metastasis, and rheumatoid arthritis. Her past surgical history included appendectomy in 1945, hysterectomy in 1966, abdominal aortic aneurysm repair in 1998, and parathyroidectomy in 1998. She had bronchoscopy and mediastinoscopy 2 weeks before admission for the current surgery. The result of this bronchoscopy was left lower lobe adenocarcinoma, and the result of mediastinoscopy was negative. The patient had a history of cigarette smoking of one pack per day for 40 years. Medications included atenolol, lipitor, isosorbide, metachlopramide, and colace. The patient had allergies to sulfa and penicillin. The patient received a complete cardiovascular workup before surgery. A persantine-thallium test showed mild ischemia in the distribution of the left anterior descending area and a left ventricular ejection fraction of 80%. A coronary artery angiogram showed 30% stenosis in the right ventricular branch, 40% stenosis in the posterior descending artery of the right coronary artery, a normal left coronary arterial system, and 30% to 40% stenosis of the third diagonal branch. Carotid duplex examination showed 99% occlusion of the left carotid artery and 16% to 49% occlusion of the right carotid artery. The pulmonary function test showed that the forced expiratory volume in 1 second was at 82% predicted value.

The patient was brought to the operating room after intravenous administration of 1 mg of midazolam. Standard monitors were placed. Two large-bore intravenous catheters were placed; before induction, a radial arterial catheter was unsuccessfully attempted. The patient was induced with 2 mg of midazolam, 250 μg of fentanyl, 100 mg of ketamine, and 7 mg of vecuronium. A 37F left-sided double-lumen endobronchial tube was placed by an experienced anesthesiologist. After intubation of the trachea, the lung fields were auscultated to check for proper placement. At this time, respiratory sounds were diminished on the right side. A pediatric fiberoptic bronchoscope was used to verify the double-lumen endobronchial tube placement. Through the tracheal lumen, the right mainstem bronchus was visible, but the bronchial lumen was contaminated with blood and was poorly visible. At the same time, the patient's oxygen saturation decreased from 98% to 91%. The patient's blood pressure also decreased from 110 mmHg systolic to 90 mmHg systolic, and the heart rate was 92 beats/min. Phenylephrine was infused to maintain the blood pressure over 100 mmHg systolic. The double-lumen endobronchial tube was removed, and a size 8 single-lumen endotracheal tube was placed without difficulty. The oxygen saturation remained in the low 90s. The patient also presented with abdominal distention, and peak airway pressure began to increase from 24 cmH_2O to 38 cmH_2O. At this time, an adult fiberoptic bronchoscope was placed through the single-lumen endotracheal tube. A full-thickness tracheobronchial injury was noticed at the membranous portion of the carina (Fig 1), and the diagnosis of tracheobronchial rupture was made. After discussion with the surgeon and the patient's family, the decision was made to repair the tracheal injury through a right thoracotomy on cardiopulmonary bypass (Fig 2). During the surgery, a rupture was noticed

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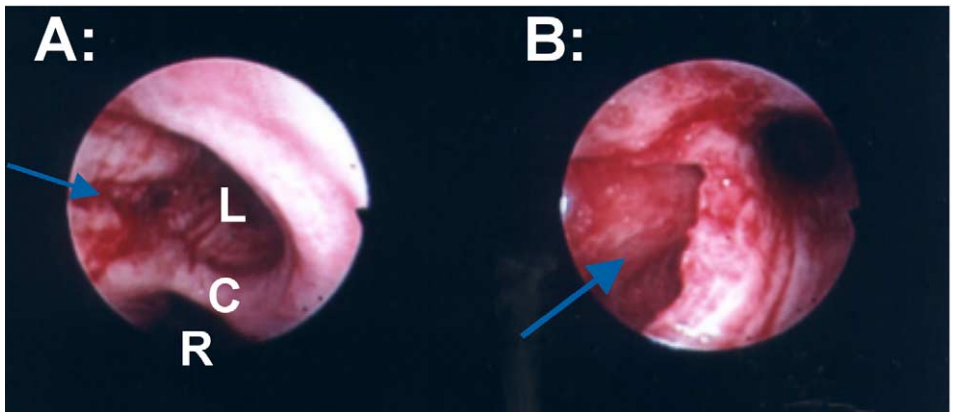

Fig 1. (A) After intubation, fiberoptic bronchoscopic examination showed the traceobronchial injury at the membrane portion of the trachea extended to the left main bronchus. The arrow indicates the injury site. L, left main bronchus; R, right main bronchus; C, carina. (B) The enlarged picture focused on the injury site.

in the membranous portion of the trachea and extended to the left main bronchus. The tracheobronchial rupture was repaired, and the patient was weaned from cardiopulmonary bypass and remained sedated and intubated on admission to the intensive care unit, successfully surviving the surgical repair.

In the intensive care unit, fiberoptic bronchoscopy examination was used every other day to examine the surgical repair. On postoperative day 7, the tracheobronchial rupture was noted to be completely healed. The patient's recovery was complicated by a stroke postoperatively. She was weaned off the ventilator over the next 14 days and discharged to a nursing care facility on postoperative day 32. She ultimately expired 8 months postoperatively from an unrelated cause.

DISCUSSION*†

Tracheobronchial rupture is defined as any injury to the trachea and bronchi localized between the level of the cricoid cartilage and the division of the lobar bronchi into their segmental branches.[1] The number of noncardiac thoracic surgical operations has dramatically increased in recent years and is expected to increase further in the future. Double-lumen endobronchial tubes have been widely used in those thoracic cases and other cardiovascular cases. There are complications associated with the placement of double-lumen endobronchial tubes. In 1 study, the frequencies of specific complications were decreased oxygen saturation, 9%; increased airway pressures, 9%; poor lung isolation, 7%; air trapping, 2%; and airway trauma 0.4%.[3]

Tracheobronchial rupture is a rare complication of both single-and double-lumen endobronchial intubation. It may also be caused by other factors, such as blunt thoracic trauma,[4-6] explosion injuries, and penetrating or gunshot wounds.[1] The contributing factors during endotracheal intubation include operator errors (multiple attempts, inexperienced physicians), equipment selection (inappropriate use of stylets, cuff overinflation, malposition of the tube, improper tube size), and patient actions (abrupt movements, excessive coughing).[7-10] Other risk factors contributing to the tracheobronchial injuries include older age females (>50 years), critical illness, steroid use, chronic obstructive pulmonary disease, tracheomalacia, and young teenagers.[2,6,11] The most involved injury sites are the membranous portions of the trachea and the carina.[2]

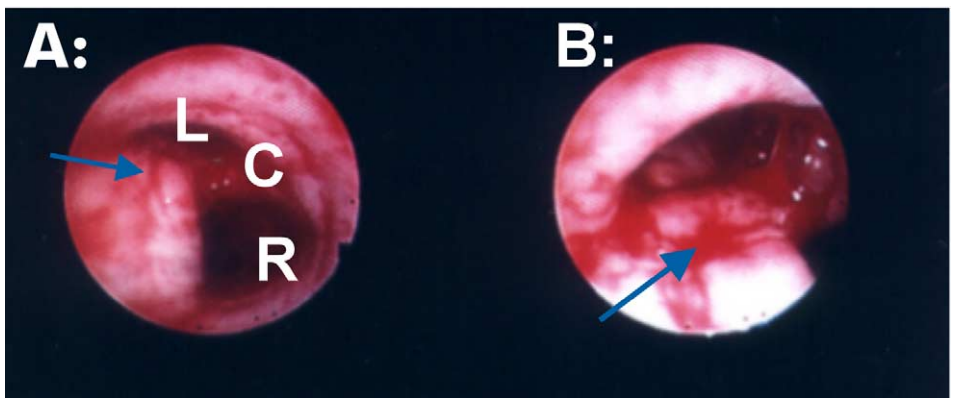

Fig 2. (A) This picture was taken after the surgical repair of the tracheobronchial injury. The arrow indicates the repair site. L, left main bronchus; R, right main bronchus; C, carina. (B) The enlarged picture focused on the injury site.

In this case, an experienced anesthesiologist performed the intubation with a size 37 left double-lumen endobronchial tube without difficulty on the first attempt with no resistance discovered on placement. A stylet was used to facilitate the intubation and was removed after complete intubation was achieved. Determining when to remove the stylet is controversial. A study was performed to determine if leaving a stylet in the double-lumen endobronchial tube for the entire intubating procedure improves the accuracy of placement on the initial attempt, without introducing complications.[12] The conclusion of this study was that retaining the stylet for the entire intubation procedure allows for a more rapid, accurate placement of the direct laryngoscopy without increasing the incidence of tracheobronchial mucosal injury.[12] Choosing the proper size tube for intubation is very important. The most common methods are chest x-ray and computed tomography scan. The diameters of the trachea and left mainstem bronchus have been used to predict the double-lumen endobronchial size. Although the results are not consistent, they can provide certain prediction for the size to use.[13-15]

Because untreated tracheobronchial rupture is a fatal complication, immediate recognition is very important in managing this potentially fatal situation. Diagnosis of such conditions may be difficult, and many cases were diagnosed up to 126 hours after injuries.[10,16] Thus, a high index of suspicion must be maintained when the following symptoms are presented: mediastinal and subcutaneous emphysema, respiratory distress, hemoptysis, and retrosternal pain.[1,2,17]

The treatment modalities are controversial. Operative management for such injuries was the only treatment in the past, but nonoperative treatment in certain cases has been advocated recently and with excellent clinical results.[13,18-20] The indications for surgical repair are based on the overall clinical findings including signs, radiology, and bronchoscopy. Respiratory distress in the absence of a pneumothorax, rapidly increasing subcutaneous and mediastinal emphysema, and/or pneumothorax showing continuous air leak and no reexpansion of the lung after intercostal suction drainage are strong indicators for the need for surgery. Tracheobronchial injuries involving the paracarinal region, full thickness, and greater than 2 cm are also indications for surgery.[1] Nonsurgical therapy includes intubation with the cuff inflated distal to the tear, chest tube drainage, if necessary, and antibiotic management. The broad-spectrum antibiotics against common tracheobronchial flora have been used to prevent nosocomial respiratory infection and mediastinitis. The reported antibiotics for this use include piperacillin-tazobactam, ciprofloxacin, metronidazole, amikacin, and penicillin.[9,18,20] Conservative management should be reserved for patients with small lacerations, injuries amenable to adequate cuff positioning, or injuries that do not involve the whole thickness of the wall. Patients with poor general condition and high operative risk should also be managed conservatively.[1,16,21]

Because the incidence of tracheobronchial ruptures caused by endotracheal intubation is so rare and life-threatening, early diagnosis and intervention are vitally important. Respiratory distress and subcutaneous emphysema are the most common clinical findings. Early bronchoscopy is the most effective diagnostic tool when airway injury is suspected.[1,8,16,21,22] Both surgical and nonsurgical therapies have been used. The final decision should be based on clinical, radiologic, and endoscopic findings. In summary, the authors present a rare case of tracheobronchial rupture secondary to endotracheal intubation using a double-lumen endobronchial tube, in which the patient was surgically repaired and survived the episode.

COMMENTARY—SURGEON—1§

This report describes a 76-year-old woman who suffered a distal, full-thickness tracheal laceration as a consequence of double-lumen endotracheal tube intubation. The planned procedure was a left lower lobectomy for malignant disease. Mediastinoscopy and bronchoscopy performed 2 weeks prior had been negative, except for the known left lower lobe adenocarcinoma. In particular, no anatomic or pathologic abnormalities of the trachea were noted at the time of the previous bronchoscopy. Difficulty with ventilation, subcutaneous air and abdominal distention were noted immediately. The double-lumen tube (DLT) was replaced with a standard endotracheal (ET) tube and a full-thickness injury at the level of the carina posteriorly was noted. This was repaired with cardiopulmonary bypass through a right thoracotomy. The patient recovered but succumbed to unrelated causes 8 months later.

Tracheal injuries secondary to intubation are uncommon but do occur. Risk factors that may lead to this complication include operator inexperience, inappropriate equipment, underlying tracheal pathology such as malignant involvement or unrecognized stenosis, chronic illness, chronic steroid use, and inflammatory diseases of the trachea. One of the most common causes is that of operator error. The anesthesiologist should not only be experienced but should also have experience with the safe placement of DLTs. Stylets are dangerous and should be used with extreme caution. They should be removed immediately after the tube is beyond the cords. Their use should be confined to negotiating a difficult angle for laryngeal entry. They should not be used to traverse the trachea and bronchi because this is a blind maneuver. The modern DLT tube is designed, if properly used, to enter the correct bronchus. If this does not occur easily, then a safe method to position the tube, such as with fiberoptic bronchoscopy, is appropriate. This also allows an assessment of the airway size, which may indicate that the tube is too large. Advancing the tube under direct vision is the best way to avoid injuries in cases in which the tube does not position easily.

The diagnosis is usually obvious, but the presence of blood in the ET tube should prompt an airway examination. Other signs include pneumothorax, difficult ventilation, surgical emphysema, and hemoptysis.

Prompt recognition and treatment are the solution to this complication. Any suspicion of such an injury should be followed by an intraoperative bronchoscopy. With a severe injury, a flexible esophagoscopy is suggested to rule out a concomitant esophageal injury. Failure to recognize this will have disastrous consequences. The management of serious tracheobronchial injuries is immediate surgical repair, unless there is some overwhelming reason to the contrary.[16] There is no place for the

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conservative management of this syndrome, unless the injury is not full thickness and only represents a mucosal laceration.[7] If left untreated, a full-thickness injury will be fatal. Mediastinitis, pneumonia, tracheoesophageal fistula, and respiratory compromise will result. Repair at a later date will be more difficult if not impossible and will be far less likely to be successful. The approach to repair of a tracheal laceration can be through the neck, through a right thoracotomy, or through a sternotomy, and is dependent on location and extent of the injury. Obviously, the cervical incision can only be used for injuries of the superior one half of the trachea.

In this case, the operative management for the tracheal injury was appropriate. A right thoracotomy provides excellent access to the posterior carina, allowing meticulous repair with interrupted sutures. The use of cardiopulmonary bypass adds a degree of complexity, which is not necessary. With the necessary heparinization, the risk of undue bleeding into the airway is increased, as are other bleeding complications. To avoid bypass, an uncut small endotracheal tube can be advanced into the left mainstem bronchus or a small left-sided double-lumen endobronchial tube could have been advanced under bronchoscopic control. Both of these techniques would allow ventilation to continue and avoid bypass. Furthermore, a small catheter (a standard nasogastric tube will serve well) could be advanced through the endotracheal tube and high-frequency jet ventilation used, again, to avoid bypass. This would have been the preferred technique so that tracheal repair can be performed without the interference of bulky endotracheal tubes.

The trachea in the neck is easily accessible for repair. A posterior injury requires an anterior tracheotomy to gain access. Authors have described the intraoperative use of the flexible bronchoscope to facilitate the operation.[23] The repair is with interrupted, meticulously placed sutures.[24-26] An absorbable such as Vicryl or polydioxanone, 3-0 or 4-0, is appropriate and the knots may be tied on the inside without sequelae. A midline sternotomy, with retraction of the aortic arch to the left and the superior vena cava to the right (so-called transpericardial approach used in organ procurement and other carinal procedures), goes right to the carina and would have been a reasonable approach for this patient. Again, this would have avoided the use of cardiopulmonary bypass, which probably was not necessary.[27]

As is usually the case, the best treatment for these injuries is avoidance. Experience, appropriate equipment of appropriate size, the ready availability of a flexible bronchoscope when difficulties occur, and a high degree of caution are necessary. A high index of suspicion will allow prompt management when the unavoidable occurs.

COMMENTARY—ANESTHESIOLOGIST—2‡

In 1949, Carlens introduced a new flexible DLT into clinical practice for the purpose of differential bronchospi metry.[27] One year later, this same tube was used to isolate the lungs during intrathoracic surgery for pulmonary infection.[28] Variations of the Carlens tube have evolved to the modern-day polyvinylchloride (PVC) plastic DLTs that resemble the Robertshaw DLT in design but are intended for single use only. A variety of PVC DLTs are sold by 4 manufacturers in the United States: Portex (Portex, Keene, NH), Rusch (Rusch, Duluth, GA), Sher-I-Bronch (Sheridan, Argyle, NY), and BronchoCath DLT (Mallinckrodt Medical, Inc, St. Louis, MO).[29] Both right-and left-sided models are available in 4 adult sizes: 35F, 37F, 39F, and 41F. A 32F BronchoCath DLT is available for use in small adults and larger children.[30]

Tracheal disruption after elective intubations occurs in less than 1% of patients intubated with DLTs; however, the actual incidence is probably underreported. More commonly, airway injury in patients intubated with a DLT results in tracheal irritation or laryngitis. Serious airway damage was a recognized complication of the red rubber DLTs. It was not surprising that when PVC DLTs were introduced in the early 1980s they were initially thought to be much safer than the red rubber DLTs.[31] However, shortly after the introduction of PVC DLTs, reports of airway injury began to appear in the medical literature.

A comprehensive literature review of airway rupture resulting from the placement of DLTs is reported by Fitzmaurice and Brodsky.[32] They identified 33 reports of tracheobronchial rupture caused by DLTs published between 1972 to 1998. They listed direct trauma during intubation, cuff overinflation, and preexisting airway pathological disease as the 3 most common risk factors for airway rupture when either red rubber or PVC DLTs were used. The airway trauma presented in these reports manifested as a persistent air leak, subcutaneous emphysema, airway hemorrhage, or tension pneumothorax. In some instances, the signs of injury were not evident for many hours after the initial insult when rupture into the mediastinum or pleural space occurred.[33] If tracheobronchial rupture is suspected, immediate recognition is imperative. Fiberoptic bronchoscopy allows for early diagnosis and prompt surgical intervention if indicated.

The present case reports tracheobronchial rupture after intubation with a double-lumen endobronchial tube in a 76-year-old, 39-kg, 142-cm white woman who had several preexisting risk factors for tracheobronchial injury. These risk factors include being a female patient >50 years old, a history of chronic obstructive pulmonary disease, preexisting pathological airway disease (left lower lobe adenocarcinoma), and short stature.[33,34] Another potential risk factor includes exposure to radiation therapy that may contribute to scarring and friability of the airways.

Several points are worth consideration with regard to the authors' selection of a 37F left-sided double-lumen endobronchial tube for this patient. Examination of the chest radiograph and computed tomography scan is useful for determining tracheal width and left bronchial width, 2 factors that can be used to select an appropriate-sized left double-lumen endobronchial tube.[30,35] Because the authors did not report the tracheal or left bronchial measurements, it is not known if the patient would have received a 35F DLT or perhaps a 32F DLT if her tracheal diameter was <12.5 mm in width. Alternatively, height guidelines could be used to select the DLT size, although this method may not be as accurate. For females, Slinger recommends using a 37F DLT for patients >1.6 m in height and a 35F DLT for those <1.6 m.[36] The authors did report the patient's height as

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1.42 m; therefore, a 35F DLT would have been selected according to these guidelines.

Operator errors (multiple intubation attempts, inexperienced physicians) contribute to tracheobronchial rupture.[33] This case reports that an experienced anesthesiologist performed the intubation without difficulty on the first attempt. This same description during intubation with DLTs resulting in tracheobronchial rupture is described in the literature.[37] The manufacturers of PVC DLTs recommend removal of the bronchial lumen stylet as soon as the tip of the tube traverses the vocal cords. Lieberman et al[38] recommend retaining the stylet throughout the entire intubation sequence with the DLT to facilitate rapid, accurate placement without introducing tracheobronchial mucosal injury; however, evidence that the stylet is safe is limited to this one relatively small study. To date, this case presented in the current report is the only published report of major airway trauma attributed to a stylet retained during the entire DLT placement sequence.

The clinical manifestations of tracheal injury in surgical patients (subcutaneous emphysema, pneumomediastinum, pneumothorax, respiratory impairment, hemoptysis, and retrosternal pain) appear intraoperatively or in the immediate postoperative period. These symptoms are not specific and may be present in the absence of tracheobronchial rupture. A chest radiograph may confirm the presence of tracheobronchial rupture; however, in the operating room environment fiberoptic bronchoscopy is a readily available and reliable method to make a definitive diagnosis. The patient in the current case presents early evidence of tracheobronchial rupture that was rapidly diagnosed. Immediately after intubation, the authors describe diminished breath sounds in the right thorax concurrent with hemodynamic instability, desaturation, an increase in peak airway pressure, and the presence of hemoptysis. Direct visualization of a full-thickness tracheobronchial injury of the membranous carina with extension to the left mainstem bronchus was confirmed with fiberoptic bronchoscopy and surgical intervention ensued in a timely fashion. The patient survived this airway complication, but because of her multiple comorbidities, she sustained a cerebrovascular accident in the perioperative period and ultimately died several months later.

Although the incidence of tracheobronchial rupture associated with placement of DLTs is very low, anesthesiologists must employ measures to further minimize this potentially life-threatening complication. Fitzmaurice and Brodsky recommend the following to reduce the chance of a significant airway injury from a DLT: (1) PVC DLTs should be used in preference to the red rubber DLT, (2) the largest PVC DLT that will safely fit the airway should be chosen, (3) airway size should be measured from either a chest radiograph or computerized tomographic scan to guide size selection for left-sided BronchoCath DLTs,[39,40] (4) a DLT should never be forcibly advanced, (5) avoid advancing the DLT too deeply into the bronchus, (6) inflate both the bronchial and tracheal cuffs slowly and be careful not to overinflate the bronchial cuff in particular, (7) avoid nitrous oxide if possible, (8) deflate both cuffs when moving the patient or repositioning the DLT, and (9) a fiberoptic bronchoscope should always be available for inspection of the airway.[32]

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