administrations of postpartum epidural fentanyl in routine use, we have observed no cases of respiratory depression.

Because of the short, predictable nature of the effects produced by epidural fentanyl, we have found that the analgesia produced by 50 μg of epidural fentanyl is useful in postcesarean patients. The commercial preparation of fentanyl is preservative free, thus obviating the needs for special formulations, as is found with morphine. If a longer duration of action is required, repeat injections of 50 μg of fentanyl, after the initial analgesia disappears, will provide further analgesia.

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Anesthesiology
63:698–700, 1985

# Tracheal Rupture Following the Insertion of a Disposable Double-lumen Endotracheal Tube

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Fortunately, tracheobronchial rupture following tracheal intubation is a rare complication. Single-lumen, endobronchial, and double-lumen endotracheal tubes can cause serious airway injury.[1–3] Nondisposable red rubber and disposable polyvinylchloride (PVC) single-lumen tubes have been implicated in tracheobronchial lacerations. In contrast, nondisposable red rubber tubes have been responsible for all double-lumen endotracheal tube injuries.[2,4] No airway injuries have been reported with the recently introduced disposable PVC double-lumen tubes.

Risk factors associated with tracheobronchial rupture include inexperienced endoscopists, intubating stylets, multiple vigorous attempts at intubation, tracheal abnormalities, overdistension of tracheal or bronchial cuffs with high pressure, low-volume cuffs, and old age.[5–8] We recently anesthetized a patient, in whom none of these factors were present, who sustained a tracheal rupture following an "atraumatic" endotracheal intubation with a disposable, left-sided double-lumen tube.

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Received from the Department of Anesthesiology, Wilford Hall USAF Medical Center, Lackland AFB, Texas 78236-5300. Accepted for publication July 12, 1985.

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Key words: Equipment: double-lumen endotracheal tube. Complications: tracheal rupture.

## Report of a Case

A 59-year-old woman, 1.6 m in height, weighing 65 kg, who had squamous cell carcinoma of the lung was admitted for right middle and right lower lobectomies. Significant medical history included a left-sided cerebrovascular accident without sequelae in 1950 and a total abdominal hysterectomy and bilateral salpingo-oophorectomy for endometrial carcinoma in 1976. There was no preoperative history of medications, including steroids. Preoperative laboratory studies, including complete blood count, serum electrolytes, and electrocardiogram were normal. A right, lower-middle lobe, 3-cm nodule was seen on a chest roentgenogram. Pulmonary function studies revealed a forced vital capacity of 4.50 l and a $FEV_1$ if 1.96 l.

Premedication consisted of diazepam, 10 mg orally. Two peripheral iv catheters and a left radial arterial catheter were inserted. Anesthesia was induced with diazepam, 10 mg iv, followed by thiopental, 250 mg, and succinylcholine, 80 mg iv. A left-sided 39 French O.D. Broncho-Cath® National Catheter Corporation endobronchial tube with stylet then was inserted into the trachea. Immediately after the tip of the tube passed the vocal cords, its insertion was stopped and the stylet removed. The tube then was rotated 90 degrees counterclockwise and advanced without resistance until 27.0 cm (at the lips), where mild resistance was encountered. The resistance experienced was felt to be the normal resistance of the left mainstem bronchus and carina as the tube advanced into position. The tracheal cuff was inflated to "minimal occlusion" with 5.0 ml air, and 2.0 ml air injected into the bronchial cuff. Initial ausculatation of the chest revealed breath sounds on the right, with absent breath sounds on the left, while both lumens were

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patent or selectively clamped. This suggested a right mainstem intubation. Both cuffs then were evacuated, the tube withdrawn 5.0 cm, rotated 45 degrees more to the left, and advanced without resistance to a depth of 27.0 cm. The occlusion cuffs were reinflated as previously described. Correct tube placement was verified by bilateral, equal breath sounds with both lumens patent, absent left lung breath sounds with right lung sounds with the left (bronchial) lumen clamped, and the opposite findings with the tracheal lumen clamped. At no time was any abnormal resistance to tube passage encountered. The patient subsequently was turned into the left lateral decubitus position, and correct tube placement was reconfirmed by auscultation. Anesthesia was maintained uneventfully with isoflurane, 1%, inspired in oxygen. Pancuronium 5 mg, was administered iv for muscle relaxation. The left lung only was ventilated during the lobectomies. At all other times both lungs were inflated. Arterial blood gas tensions and *p*H were satisfactory throughout the entire procedure.

Immediately before chest wall closure, the surgeons noted an expanding, baseball-sized mass on the right posteriolateral tracheal wall just above the carina. Deflation of the tracheal cuff was associated with a significant reduction of the mass. Exploration of this area revealed a 5.0-cm longitudinal laceration in the membranous portion of the right posteriolateral tracheal wall. The laceration originated 1.0 cm proximal to the carina and extended cephalad, with the tracheal cuff occupying the upper two-thirds of the defect.

Tracheal repair was performed with two layers of 4-0 proline suture, and a pericardial pedical flap was sutured over the site for reinforcement. Neuromuscular blockade was reversed with neostigmine, 5 mg, and glycopyrollate, 1.2 mg, iv, followed by tracheal extubation in the operating room. Postoperatively, the patient did well, with no evidence of tracheal leak or mediastinitis. On the eleventh postoperative day, she was discharged from the hospital.

## Discussion

Since the introduction of double-lumen catheters for endobronchial administration of anesthesia by Bjork *et al.* in 1952[9] controversy has existed regarding their benefits and risks. Isolation of one lung is indicated to minimize infection or hemorrhage, in cases of unilateral bronchopleural or bronchopleural cutaneous fistulae, or to allow unilateral pulmonary lavage.[10] Collapse of the operated lung improves surgical exposure and shortens the duration of operation.[11,12] Thus, insertion of a double-lumen tube is routine for all scheduled thoracotomies in some centers.[13] Modern disposable, double-lumen endobronchial tubes with low-pressure, high-volume cuffs, large and easily suctioned lumens, and ease of placement make one-lung anesthesia even more attractive.[10]

Isolated tracheal injury is also rare; most serious airway injuries involve the intubated mainstem bronchus.[1,2] Signs of tracheobronchial injury such as hemorrhage, cyanosis, air leak, pneumothorax, subcutaneous emphysema, or compliance changes[2,16,17] also were notably absent. This emphasizes the serendipitous discovery of this laceration in our patient and concurs with the paucity of physical findings reported by several investigators.

The exact mechanism for this unusual injury remains obscure. Surgical trauma was ruled out, since the procedure did not involve the mediastinum and the tear began in the tracheal lumen. Oversized tubes and/or overinflated cuffs have caused tracheal rupture.[5] However, our tube passed easily, the tracheal cuff was inflated to "minimal occlusion," and only 2.0 ml air was injected into the bronchial cuff. Tornvall *et al.*[6] suggest that the bronchial cuff should be deflated before repositioning in the lateral decubitus position to prevent bronchial injury.[6] We did not do this, but the intubated bronchus in our patient was uninjuried. Vigorous coughing with tracheal overpressure,[1,18] and other vigorous motions that may acutely overdistend the trachea,[7,19] also can cause rupture. Such events did not occur in our patient. The tube tip might have caused the initial injury, either directly or by folding back upon itself. However, the stylet was removed as soon as the tip advanced past the vocal cords, and absolutely no abnormal resistance was encountered with tube advancement. We could not explain a right posteriolateral tracheal laceration caused by the tip when it was inserted through the cords anteriorly and rotated to the left. Presumably, a tear in the right mainstem bronchus during the first intubation attempt could have dissected posteriorly under positive pressure ventilation. The membranous trachea becomes thin, inelastic, and stretched in emphysema, although the surgeons noted an otherwise normal tracheobronchial tree. Our incident is similar to the report by Thompson *et al.*,[8] who reported a tracheal rupture in a patient with lung cancer and chronic obstructive pulmonary disease (COPD) following intubation with a Magill tube. Evidently, COPD also predisposes the trachea to injury with endotracheal tubes.

This case permitted visualization of the evolution of a tracheal tear and can explain the many reports of delayed discovery of tracheal disruptions.[6,17] After a partial-thickness tracheal wall laceration, air dissects into the adventitia and expands it, producing aneurysmal dilatation of the membranous tracheal wall. Such dilatation may take hours, and no sign of injury occurs in some cases until rupture into the mediastinum or pleural space. Indeed, we would have been totally unaware of this serious injury if the surgeons had not "routinely" inspected the pleural space before closure. This emphasizes the need for inspection of the mediastinum while both lungs are ventilated. The surgeons observed no tracheal abnormality at the beginning of the procedure when one-lung ventilation was employed, at the time when the right lung and trachea were exposed to ambient pressure.

Double-lumen tube tracheal intubation and one-lung ventilation will continue to be used for thoracic surgical procedures because they provide optimal operating conditions. As outlined here, tracheal lacerations may occur with any type of "atraumatically" placed endotracheal tube. No apparent signs of injury may occur until hours after the injury. This is crucial, because surgical repair and successful results without complications are contin-

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gent upon early recognition and therapy.[1,5,6,8,16,17,19] Mediastinal inspection while both lungs are ventilated should be accomplished after every thoracic procedure if it does not involve indue risk. If such an inspection is not possible, bronchoscopy should be performed immediately if a tracheal laceration is suspected.[2,4,16,17]

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Anesthesiology
63:700–703, 1985

# Application and Limitation of Somatosensory Evoked Potential Monitoring during Thoracic Aortic Aneurysm Surgery: A Case Report

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Somatosensory cortical evoked potential (SEP) monitoring has been recommended for use during surgery on a thoracic aortic aneurysm to predict spinal cord ischemia from clamping of the aorta and to minimize neurologic sequelae.[1–3] However, the reliability of SEP for monitoring spinal cord function during such surgery has not been verified.

Intraoperative changes in cord function may not be reflected by changes in SEP, which are transmitted primarily by the dorsal columns.[4] Specifically ischemic changes of the anterior cord during cross-clamping of the aorta may be associated with complete motor loss with preservation of SEP,[4] although such an episode has never been reported before, as occurring during thoracic aortic aneurysm surgery.

We describe a case of postoperative paraplegia in a patient with an episode of transient reversible obliteration of SEP during surgery on a thoracic aortic aneurysm.

## Report of a Case

A 55-year-old man with a history of hypertension, diabetes, and mild left hemiplegia due to previous subcortical bleeding of the right temporal lobe was scheduled for removal of a dissecting thoracic aortic aneurysm of the IIIb type.[5] An operation was scheduled for grafting of the thoracic aorta using temporary bypass from the left axillary to the left femoral artery during cross-clamping of the aorta.

Anesthesia was induced and maintained with fentanyl and diazepam iv supplemented with nitrous oxide. A four-channel signal averager was used to measure SEP (DISA 1500 system®, DISA). The recording electrode was placed 2 cm posterior to Cz according to the international 10–20 system (Cz'). The referenced electrode was placed at Fpz. The

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Received from the Department of Anesthesiology, National Cardiovascular Center, 5-7 Fujishirodai, Suita, Osaka 565 Japan. Accepted for publication July 12, 1985.
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Key words: Complications: paraplegia. Monitoring: somatosensory evoked potential.

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