J Anesth (2007) 21:76–79
DOI 10.1007/s00540-006-0463-0

Journal of Anesthesia

Bilateral tension pneumothoraces following jet ventilation via an airway exchange catheter

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Abstract
We report a case involving a 55-year-old man who had a recent resection of tracheal carcinoma and tracheal re-anastomosis. He subsequently developed tracheomalacia and anastomotic dehiscence requiring airway stenting via an armored endotracheal tube (ETT). Placement of the armored ETT was technically difficult. It required insertion of an airway exchange catheter through the tracheal stoma to oxygenate, ventilate, and serve as a guide for ETT placement through the tracheotomy and across the dehiscence. During transtracheal jet ventilation our patient developed bilateral tension pneumothoraces requiring cardiopulmonary resuscitation and chest tube placement. The patient was quickly recovered, stabilized, and later discharged after a prolonged intensive care unit (ICU) course. We review the recommendations for jet ventilation via airway exchange catheters, common problems during this technique, and potential methods for avoiding these problems. The risk of barotrauma and pneumothoraces during jet ventilation via an airway exchange catheter should be kept in mind.

Key words Barotrauma · Jet ventilation · Airway exchange catheter · Pneumothorax

Introduction

Airway management is one of the most fundamental and, at times, most difficult aspects of an anesthesiologist's responsibilities. Difficulties with airway management leading to inadequate ventilation, esophageal intubation, and difficult tracheal intubation have collectively accounted for over 37% of claims in the American Society of Anesthesiologists (ASA) Closed Claims Project database since 1993 [1]. One of the techniques for managing a difficult airway is the use of an airway exchange catheter (AEC). Besides helping to secure an airway, the AEC also allows limited oxygenation and ventilation while a more definitive airway is established. We describe a complication associated with the use of this device.

Case report

Our institutional policy does not require patient consent for the publication of a single-patient case report. A 55-year-old man with a past medical history significant for smoking, chronic obstructive pulmonary disease (COPD), atrial fibrillation, and hypertension, presented in respiratory distress, inspiratory stridor, and expiratory wheezing. Workup revealed a partially obstructing tracheal mass 4 cm proximal to the carina, measuring 5 cm in diameter by computed tomography (CT) scan. An urgent resection of tumor and end-to-end anastomosis of the tracheal segments was performed via a suprasternal approach. The perioperative course was uneventful. Upon conclusion of the procedure, the patient was kept intubated, his chin was sutured to his chest to restrict the neck movement, and he was transferred to the intensive care unit (ICU) in stable condition.

On postoperative day (POD) 1, his oxygen requirements increased, such that fraction of inspired oxygen ($F_{I_{O_2}}$) of 1.0 and positive end-expiratory pressure (PEEP) of 15 cm H_2O were required to keep peripheral oxygen saturation ($S_{P_{O_2}}$) at more than 94%. Upon workup for his increased oxygen requirement, he was noted to have a left-sided pneumothorax, which was drained with a chest tube. Over the next 5 days he was unable to be weaned from mechanical ventilatory support. Fiberoptic bronchoscopy (FOB) revealed

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Received: May 15, 2006 / Accepted: September 30, 2006

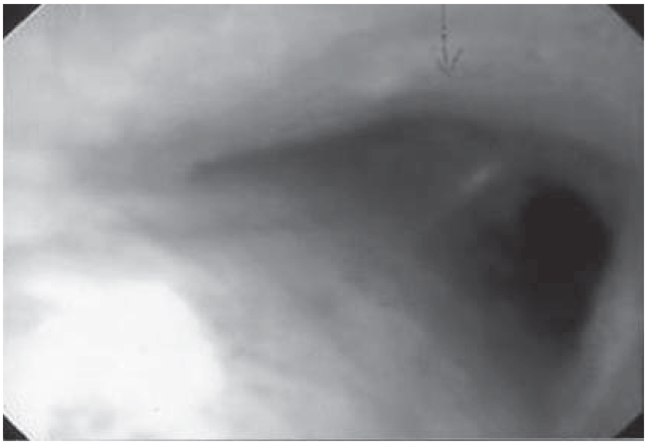

Fig. 1. Fiberoptic view of distal trachea, showing tracheomalacia and bronchomalacia of the left mainstem bronchus

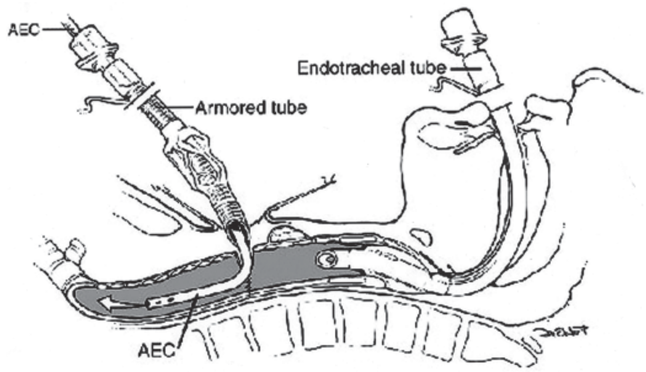

Fig. 2. Placement of airway exchange catheter (*AEC*) through the tracheal stoma to guide the placement of armored tracheostomy tube and to allow jet ventilation. The oral endotracheal tube is in situ and open to air

tracheomalacia distal to the surgical anastamosis and bronchomalacia in the left mainstem bronchus (Fig. 1).

On POD 6, the patient was returned to the operating room (OR) for rigid bronchoscopy and stenting of the bronchomalacic segment. Following pre-oxygenation and IV induction of anesthesia, he was extubated to allow placement of a rigid bronchoscope. A rigid bronchoscope could not be passed due to technical difficulty in visualizing the larynx. Reintubation of the patient with a 7.5-mm internal diameter (ID) tube was difficult, requiring the use of a gum elastic bougie; the best view on direct laryngoscopy was a grade III (Cormack and Lehane). He was transferred back to the ICU for continuing ventilatory assistance.

Repeat FOB on POD 9 revealed partial dehiscence of the surgical anastomosis. He was again brought to the OR for creation of a tracheotomy and placement of an armored endotracheal tube (ETT) through the tracheotomy in an effort to buttress (and protect) the anastomosis. Anesthesia was induced and maintained with intravenous infusion of propofol and intermittent boluses of fentanyl and cisatracurium. Creation of a tracheotomy resulted in worsening of gas exchange due to the loss of volume through the tracheotomy. Placement of a 7.0-mm ID armored ETT through the tracheotomy was technically difficult because of calcified tracheal rings and close proximity of the tracheotomy to the anastomotic suture line. Arterial blood gas at this time showed pH 7.19, Pa_{CO_2} 86 mmHg, and Pa_{O_2} 84 mmHg on F_{IO_2} 1.0, with PEEP of 10 cmH_2O. Subsequent attempts to place a smaller (6.0-mm ID) armored ETT resulted in much more rapid desaturation. In an effort to allow oxygenation as well as act as a guide for the armored ETT, a 14-F, 83-cm, Cook AEC (Cook Critical Care, Bloomington, IN, USA) was placed through the tracheal stoma. The oral ETT was left in place just below the vocal cords and kept open to air (Fig. 2). Using a Rapi-Fit connector (Cook Critical Care, Bloomington, IN, USA), he was ventilated via the AEC with a jet ventilator with 100% oxygen at 50 pounds per square inch (psi) with short insufflation bursts. After approximately 6–8 min of jet ventilation, he developed sudden bradycardia progressing to pulseless electrical activity (PEA). This was treated with chest compressions, atropine 0.6-mg IV bolus, and epinephrine 0.2 m IV. Decreased breath sounds were noted bilaterally and presumed bilateral pneumothoraces were decompressed with bilateral 16-gauge needles in the second intercostal spaces in the mid-clavicular lines. This resulted in immediate return of the patient's pulse. Bilateral chest tubes were placed. The patient regained hemodynamic stability without any further pharmacological support. Insertion of the armored ETT was abandoned and a regular tracheostomy tube (Mallinckrodt, Shiley, size 6; Mallinckrodt Medical, Irvine, CA, USA) was inserted through the tracheal stoma, and its position above the carina was confirmed by FOB. The patient was returned to the ICU, where he remained ventilator-dependent for 40 more days. After 60 days in the acute care facility he was discharged to an extended care facility, weaned entirely from ventilatory support. Just over a month later, the patient was readmitted to another hospital where he had his tracheal stoma decanulated and an 18-mm Y silastic studded stent placed at the level of his carina to treat his left mainstem bronchomalacia. He was subsequently returned to his skilled nursing facility.

Discussion

We report a case of bilateral tension pneumothoraces following jet ventilation via an AEC and discuss strategies for the prevention and management of complications associated with these devices.

An AEC is one of the recommended contents of a difficult airway cart and is a part of the Difficult Airway Algorithm [2]. It is often used as a guidewire over which to exchange endotracheal tubes [3], or it can act as a bougie—to guide an ETT into position during initial difficult intubation. Also, a patient with a known or suspected difficult airway may be extubated over the AEC. Should the patient subsequently require reintubation, this can be done over the AEC [4–6]. In all these situations, the AEC can be used to temporarily ventilate and oxygenate a patient until a definitive airway can be secured. The use of an AEC, however, is not without risks. These include unrecognized intubation of the esophagus, direct trauma to the tracheobronchial tree, barotrauma, and aspiration associated with an unprotected airway. Direct trauma to the paraglottic structures and tracheobronchial tree with intubating stylets has been described [7,8]. The AECs are relatively stiff catheters that can easily avulse delicate anatomic architecture if excessive force is applied. This can result in potentially catastrophic bleeding and airway trauma.

Barotrauma from jet ventilation can result in pneumothorax, and potentially rapid cardiovascular collapse. There are several possible reasons for barotrauma. First, improper AEC placement, such as a right main stem intubation, can result in delivery of inappropriately large gas volumes into distal bronchopulmonary segments. Second, typical driving pressures for jet ventilation are 25–50 psi. If these pressures are applied for an excessive inspiratory time, hyperinflation of the lungs can occur [9]. Third, many cases of barotrauma probably involve obstruction to outflow of gas, resulting in breath stacking or auto-PEEP and eventual loss of lung parenchyma integrity. This has been well characterized in mechanical lung models [10]. Upon induction of anesthesia, most patients will have complete obstruction of the nasopharynx and partial or complete obstruction of the oropharynx or hypopharyngeal airway [11]. Jet ventilation in such circumstances must be accompanied by a patent pathway for exhalation. Many of the patients who are most in need of special measures such as ventilation via an AEC also have lung disease, including obstruction to outflow. These patients are also more likely to have weakened parenchyma, making a pneumothorax more likely. The overall incidence for pneumothorax in patients ventilated with AECs was reported to be 11% in one series [5].

When an AEC is used for oxygenation/ventilation, it must be carefully positioned above the carina at the same depth that an ETT would be positioned. If resistance is met upon insertion then the AEC should be withdrawn several centimeters [12]. Lung volumes and inflation pressures must be limited; short insufflation bursts are recommended. The tidal volume delivered is determined by beginning lung volume, driving pressure, insufflation time, stylet resistance, and the total dynamic compliance. Inflation via an AEC results in a tidal volume of approximately 400 ml in lungs with normal compliance [10]. To prevent auto-PEEP, complete exhalation needs to occur before the next insufflation cycle.

Our patient suffered from pneumothoraces most likely due to inadequate exhalation via the oral ETT. As the armored ETT was advanced over the AEC it likely became an impediment to air outflow proximal to the tracheal stoma; this may have led to breath stacking and excessive airway pressures. His weakened lung parenchyma from pre-existing COPD and earlier left-sided pneumothorax may have made rupture more likely. We believe that the depth of insertion of the AEC was not responsible for the complication, as the pneumothoraces were bilateral.

It is recommended to deliver as few breaths as possible to maintain arterial saturation. Hypoxia results in rapid irreversible brain injury, while oxygenation without ventilation (apneic oxygenation) has been demonstrated for over 100 min with Pa_{CO_2} levels reaching 140 mmHg without any lasting harmful effects [11]. It is important to recognize that $F_{I_{O_2}}$ with AEC ranges from 69 to 100, depending on the amount of entrained air and, therefore, direct comparison of this technique to apneic oxygenation cannot be made. If upper airway obstruction is inevitable, it is possible to deflate the lungs via an outflow cricothyroid catheter placement [13]; this, however, would not have been possible in our patient, due to the location of the obstruction in the trachea. A high suspicion should always be maintained for pneumothorax, and rapid treatment should be implemented.

In our patient, we decided to proceed with the exchange catheter only after careful discussion with the thoracic surgeons over the potential benefits of the armored tube versus the potential harm of jet ventilating a patient with known lung disease. This case report emphasizes the rare but serious complications due to barotrauma when using jet ventilation via an airway exchange catheter. A potential area of improvement would have been to use pressure monitoring during jet ventilation. This has been well described, but requires special equipment [14–16]. Other improvements may have included using lower insufflation pressures and ensuring a clearer view of the patient's chest rise and fall to better assess adequate lung emptying.

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