A Prospective Study of the Safety of Tracheal Extubation Using a Pediatric Airway Exchange Catheter for Patients With a Known Difficult Airway*

Eric P. Loudermilk, MD; Maximilian Hartmannsgruber, MD;¹
Daniel P. Stoltzfus, MD; and Paul B. Langevin, MD

**Study objective:** To determine the usefulness of routinely inserting a hollow airway exchange catheter (jet stylet) prior to tracheal extubation of adult patients with risk factors for difficult tracheal intubation.

**Design:** Prospective, 1-year study of 40 consecutive patients undergoing mechanical ventilation who had one or more risk factors for difficult tracheal reintubation.

**Setting:** Surgical ICU of a tertiary university medical center.

**Interventions:** Study patients at risk for difficult tracheal reintubation were extubated using a No. 11 Cook airway exchange catheter (CAEC). Following tracheal extubation, the CAEC was secured, and humidified oxygen was insufflated through the central lumen (2 to 8 L/min) for a minimum of 4 h, during which oxyhemoglobin saturation (SpO₂) and respiratory frequency were monitored. Stridor or other signs of respiratory difficulty were also assessed. The CAEC was removed when it became clinically apparent that the need for tracheal reintubation was unlikely. When patients failed to respond to tracheal extubation, the CAEC was used to facilitate reintubation of these difficult airways.

**Results:** Respiratory distress necessitating tracheal reintubation occurred in 3 of 40 patients (8%). One patient failed to respond to tracheal extubation twice. None of the patients developed oxyhemoglobin desaturation (SpO₂ <90%) before or during tracheal reintubation. All four reintubations were accomplished during the first attempt using the CAEC as a stylet. The CAEC was kept in the trachea for a mean duration of 9.4 h. There were no adverse events documented.

**Conclusions:** The No. 11 CAEC is a useful and effective tool for giving patients a trial of extubation. Administration of oxygen through the CAEC diminishes the potential for hypoxia while maintaining the ability to reintubate the trachea, especially when reintubation might prove challenging. Previous data suggest that the CAEC is rigid enough to facilitate tracheal reintubation in adults; this was confirmed in the three patients in our study who required tracheal reintubation. The risk of aspiration, barotrauma, or other airway trauma during prolonged placement of the CAEC appears to be low (zero incidence in 40 patients in this study), and use of the No. 11 CAEC appeared to be safe. Since oxygen can be delivered through the CAEC, it may provide a means to safely evaluate an airway during a trial of extubation, i.e., a reversible extubation. Finally, oxygen administration through the CAEC may obviate the need for facemask or nasal cannula following tracheal extubation.

**(CHEST 1997; 111:1660-65)**

**Key words:** airway devices; Cook airway exchange catheter; difficult airway management; extubation; fiberoptic bronchoscope; intensive care unit; jet stylet; reintubation; tube exchanger

**Abbreviations:** CAEC = Cook airway exchange catheter; ETT = endotracheal tube; f = respiratory frequency; Heliox = 60% helium and 40% oxygen; SpO₂ = oxyhemoglobin saturation

Tracheal extubation of patients at risk for difficult reintubation is frequently delayed postoperatively and often becomes the responsibility of the critical care physician. Risk factors for difficult tracheal reintubation include a history of previous difficult intubation, airway edema secondary to surgical manipulation or volume resuscitation, morbid obesity, and an immobilized or unstable cervical spine.¹ Standard criteria² used to predict successful...
extubation (Table 1) assess ventilatory capacity. While all of these may be satisfied prior to extubation, none of these criteria predict the adequacy of the airway once the endotracheal tube (ETT) is removed. Hence, acute respiratory distress may develop after extubation and mandate emergency tracheal reintubation.

Reestablishing and securing the airway in these patients can be extremely challenging, often resulting in considerable morbidity and mortality. Indeed, adverse outcomes constituted the single largest class of injury in the American Society of Anesthesiologists Closed Claims Study (522 of 1,541 cases, 34%), with death or brain damage occurring in 85% of these cases. While this study reviewed operating room cases, there is no reason to suspect that airway compromise in an ICU should be associated with a lower morbidity than similar crises in the operating room. The aim of this study was to evaluate a technique for tracheal extubation that assesses the adequacy of the airway under conditions that reduce the likelihood of a hypoxic event, while at the same time maintaining the ability to reintubate the trachea.

Materials and Methods

Patient Population

With Institutional Review Board approval, 40 postoperative surgical ICU patients, over a 1-year period, had their tracheas extubated with a size No. 11 Cook airway exchange catheter (CAEC) (Cook Critical Care; Bloomington, Ind.). Patients with at least one risk factor for difficult tracheal reintubation (Table 2) were selected for the study. Subjects were enrolled sequentially. Individuals without at least one risk factor for difficult tracheal reintubation were excluded from this study. Two or more risk factors were present in 15 of 40 patients (37%). Evaluation of patients for risk factors is described below.

Patients who were known to have difficult tracheal intubations were entered into the study. Difficult intraoperative intubation was defined as the need for multiple attempts at direct tracheal intubation by more than one laryngoscopist or an unsuccessful direct laryngoscopy followed by tracheal intubation using an alternate method (eg, fiberoptic, blind nasal, or lightwand). Airway edema as a result of surgical manipulation, volume resuscitation, or intraoperative positioning was also considered a risk factor. Such patients were identified by clinical history, general appearance, direct laryngoscopy, and the cuff leak test. Note: The presence or absence of a cuff leak was assessed by auscultation of the trachea, with the ETT cuff deflated, in one of two methods. A mechanical breath was delivered at peak inspiratory pressure of 20 to 30 cm H2O, or the patient was instructed to forcibly exhale around an occluded ETT.

Patients with cervical immobility or instability, and patients with a halo cervical traction system or cervical collar in place following anterior or posterior cervical fusion, transoral odontoidectomy, or cervical laminectomy, and plating were also considered at risk for reintubation. Two patients had cervical immobility as a result of ankylosing spondylitis, and one individual had atlantoaxial instability secondary to rheumatoid arthritis. Both conditions are known to complicate tracheal intubation.

Anticipated difficulty with tracheal intubation by the anesthesiologist responsible for preoperative evaluation was also considered a risk factor. This was based on Mallampati class, thyromandibular and interincisal distances, cervical mobility, and review of previous anesthesia records. Those patients anticipated to have difficult tracheal intubations based on these criteria, who were actually not difficult to intubate by direct laryngoscopy at operation, were excluded from the study, unless other risk factors for difficult reintubation were present postoperatively.

Airway Catheter Characteristics

A No. 11 CAEC was used during tracheal extubation in all 40 patients. The airway exchange catheter is 83 cm in length and has a 4-mm external diameter and 2.3-mm internal diameter, hollow lumen (Fig 1). The No. 11 CAEC is semirigid and made of radiopaque polyurethane. It has a blunt tip and depth markings between 15 cm and 35 cm. There are 6 sideports in the distal 3 cm of the catheter (Fig 1, left). The CAEC is packaged with two proximal adapters; a 15-mm connector for attachment to a ventilator circuit or Mapleson resuscitation system and a Luer lock connector for attachment to oxygen tubing or a jet ventilator (Fig 1, right); these adapters are easily removable. The catheter is supplied in a sterile, peel-open package and is intended for one-time use.

Extubation Protocol

Prior to tracheal extubation, mechanical ventilation was weaned by using intermittent mandatory ventilation (respiratory frequency [f] = 2 breaths/min), continuous positive airway pressure (5 cm H2O), and pressure support (10 to 15 cm H2O). Tracheal extubation was considered when the patient (1) met standard extubation criteria (Table 1), (2) was conscious and

| Table 1—Standard Extubation Criteria* |
|-----------------|----------------|
| Criteria        | No.            |
| Vital capacity  | >15 mL/kg      |
| Negative inspiratory force | >20 cm H2O |
| PaO2            | >60 mm Hg at FIO2<0.50 |
| Vd/Vt           | <0.6           |
| f (spontaneous) | <25/min        |
| A-a gradient    | <200 mm Hg     |

*Vd/Vt=physiologic dead space ventilation; FIO2=fractiun of inspired oxygen.

| Table 2—Risk Factors for Difficult Intubation |
|-----------------|----------------|
| Risk Factor     | No. of Patients* |
| Airway edema secondary to surgical manipulation | 11 |
| Airway edema secondary to volume resuscitation or positioning | 7 |
| Anticipated difficult intubation | 9 |
| Unanticipated difficult intubation | 8 |
| Cervical immobility or instability | 17 |
| Morbid obesity (body mass index >40) | 3 |

*Thirty-seven percent of patients had multiple risk factors.
FIGURE 1. Pediatric size No. 11 CAEC with Luer lock connector attached to proximal end. Left: distal 3 cm of airway catheter with sideports. Right: a 15-mm connector (left) for attachment to ventilator circuit or Mapleson system and a Luer lock connector (right) for attachment to oxygen tubing or a jet ventilator.

capable of protecting the airway from aspiration, (3) was in hemodynamically stable condition, and (4) no longer required an ETT for pulmonary toilet.

The CAEC was carefully inserted through the existing ETT to avoid carinal stimulation by placing it at the same depth as the ETT tip (22 to 25 cm orally or 27 to 30 cm nasally). The ETT was then removed, and the CAEC was secured with cloth tape wrapped around the patient’s head to minimize the likelihood of dislodging it. After the CAEC was secured, humidified oxygen was insufflated through the Luer lock connector at the proximal port, at a rate of 2 to 8 L/min, titrated to keep the oxyhemoglobin saturation (SpO₂) >93%. If the SpO₂ decreased to <93% despite the delivery of 8 L/min oxygen through the CAEC, supplemental oxygen was given via facemask.

When airway edema or stridor became evident, nebulized racemic epinephrine (2.25%), 0.25 to 0.50 mL, was administered by facemask every 30 to 60 min. Inhalation of Heliox (60% helium and 40% oxygen) was delivered via facemask if stridor was refractory to racemic epinephrine.

Changes in patient position were minimalized while the CAEC was in place. The CAEC was clearly labeled as an airway catheter to prevent mistaking it for a gastric drainage tube. All patients were kept nil per os while the CAEC was in place to minimize the risk of aspiration. In all but one case, the CAEC was kept in place for a minimum of 4 h, or until the patient developed respiratory difficulty necessitating tracheal reintubation. Tracheal reintubation was performed over the CAEC if respiratory distress (defined in this study as tachypnea [\( \geq 30 \) breaths/min] or use of accessory muscles, or diaphoresis) developed that could not be relieved by racemic epinephrine or Heliox inhalation. A portable jet ventilator (Healthdyne; Marietta, Ga.) was available in case tracheal reintubation over the CAEC was unsuccessful.

The f, SpO₂, and amount of oxygen administered were measured immediately before tracheal extubation and afterwards at 5, 15, 30, 120, and 240 min while the CAEC remained in place. Patient tolerance (coughing or gagging), ease of vocalization, and evidence of airway trauma or aspiration were evaluated qualitatively while the CAEC remained in place. The CAEC remained in place for at least 4 h or until it was clinically apparent that tracheal reintubation would be unnecessary; then the CAEC was removed.

RESULTS

The study population consisted of 40 postoperative surgical ICU patients (American Society of Anesthesiologists physical status I to IV). Twenty-one patients (53%) were men, and 19 (47%) were women. Ages ranged from 17 to 83 years, with a mean age of 55.8 years. An oral ETT was in place in 31 patients (77%), and a nasal ETT in nine (23%). Tracheal extubation occurred on postoperative day 1 in 40% of patients and postoperative days 2 to 12 in the remainder. Five patients (15%) did not have a cuff leak before tracheal extubation.

Reintubation

Following tracheal extubation, 3 of 40 (8%) patients required reintubation. One patient failed to respond to extubation twice. In all four cases, reintubation was achieved over the CAEC and was easily accomplished on the first attempt without the assist-

Clinical Investigations in Critical Care

1662

Downloaded From: http://journal.publications.chestnet.org/pdAccessible.aspx?url=/data/journals/chest/20383/ on 04/13/2017
tance of flexible fiberoptic bronchoscopy or direct laryngoscopy. All four reintubations (three patients) were accomplished without oxyhemoglobin desaturation (SpO₂<90%). Three reintubations were done with a 7.0-mm ETT and the other with an 8.0-mm ETT.

**Oxygen Supplementation**

In addition to the oxygen insufflated through the CAEC, supplemental oxygen by facemask was required in 12 of 40 patients (30%). In the remaining patients (70%), supplemental oxygen was not required, obviating the need for facemask or nasal cannula following tracheal extubation. Nebulized racemic epinephrine (2.25%), 0.25 to 0.50 mL, was given to seven patients (18%) in whom stridor developed after tracheal extubation. Of these patients, two (28%) required reintubation. Heliox was administered by facemask to two patients with stridor, one of whom required tracheal reintubation.

**Catheter Tolerance**

The CAEC was left in the trachea for a mean duration of 9.4 h, the longest duration being 52 h. The CAEC was well tolerated in 39 of 40 patients (97%). One patient requested removal of the CAEC after 15 min. Because he was able to vocalize well, and the likelihood of developing respiratory distress appeared to be low, the CAEC was removed at the patient’s request 15 min after tracheal extubation. No increased incidence of coughing, excessive salivation, or other signs of airway irritation were noted while the CAEC was in place. All patients were able to vocalize with the No. 11 CAEC in place.

**Complications**

Despite securing the CAEC with cloth tape wrapped around the patient’s head, self-extubation of the CAEC occurred in one patient. In another patient, the CAEC was taped at an inappropriate depth and became dislodged into the posterior pharynx following tracheal extubation. No trauma occurred that resulted in pneumothorax or hemoptysis, nor was there any incidence of aspiration reported during the prolonged intratracheal placement of the CAEC. The diagnosis of airway trauma or aspiration was based entirely on patient symptoms. Chest radiographs to diagnose unrecognized barotrauma and fiberoptic examination to evaluate potential airway trauma or to assess for evidence of aspiration following removal of the CAEC were not done routinely, but when performed for other reasons, failed to demonstrate evidence of trauma or aspiration.

**Discussion**

Extubation of a patient with risk factors for difficult tracheal extubation is approached with concern, even in the experienced hands of the anesthesiologist and critical care physician. Mask ventilation and tracheal intubation may be difficult or impossible due to upper airway obstruction, an agitated patient, cervical immobility, or a cervical traction device that limits access to the airway. Even under the most controlled circumstances, considerable time may be needed to secure a difficult airway. The time available for tracheal reintubation is directly proportional to the ability to oxygenate the patient. When oxygen delivery is compromised, an airway must be established in minutes, or hypoxia ensues.

Extubation criteria (Table 1) do not assess patency of the airway while the ETT is in place. Indeed, to our knowledge, there are no criteria designed to assess the adequacy of the airway, and it is difficult to invariably predict which patients will develop stridor or respiratory distress following tracheal extubation due to airway compromise. In a study of 700 consecutive tracheal extubations in a surgical ICU, reintubation of the trachea was necessary in 4.4% of patients. Patients in the burn ICU or with head injury had higher failure rates of 5% and 12%, respectively. Reintubation rates of 6 to 19% have been reported in other studies. The 10% incidence of tracheal reintubation reported in our series is consistent with these studies.

Resecuring the airway following tracheal extubation can be extremely treacherous for several reasons. First, patients who fail to respond to a trial of extubation almost always have a depleted oxygen reservoir at the point when tracheal reintubation becomes necessary. These patients are frequently in respiratory distress, limiting the time available to secure the airway. Second, it is difficult to predict when a patient may develop respiratory distress following tracheal extubation, and a physician experienced in airway management may not be at the bedside should this occur. Third, the patient is in the ICU, not the operating room, where provision of an airway is optimal. Finally, technically securing the airway may be extremely challenging. Airway edema, dried blood, or secretions may render it impossible to visualize the glottic opening even by direct laryngoscopy. Fiberoptic tracheal intubation or other alternative techniques may likewise be nearly impossible under these conditions.

The jet-Stylet catheter was developed specifically for managing the difficult airway in order to avoid "trial-by-fire" extubation attempts. A variety of other devices have been used to assist in the exchange of ETTs. Nasogastric tubes, Sorenson
central venous pressure catheters, rigid ETT guides, and the fiberoptic bronchoscope have all been used with some success. However, the CAEC offers several advantages over these other alternatives.

The CAEC is made of radiopaque polyurethane, which is softer than previous tube changers, and it has a blunt tip, which potentially decreases the risk of tracheal trauma or rupture. The depth markings of the No. 11 CAEC are an important safety feature in the placement of this device. Lung laceration has been described following deep placement of a tube changer. The calibrated markings on the CAEC provide more certainty regarding depth of insertion.

When the tracheal orifice is narrow, the small diameter of the No. 11 CAEC is less likely to obstruct the airway significantly, allowing assessment of the natural airway. If necessary, it is possible to enrich the oxygen content of the gas entrained around the CAEC by placement of a facemask on the patient. In addition, the large 2.3-mm central lumen and the six distal side holes of the No. 11 CAEC prevent whipping of the catheter during jet ventilation.

We theorized that the pediatric size CAEC (No. 11) would be better tolerated than the larger, adult size but would still be rigid enough to function as a stylet for tracheal reintubation. Although we did not compare patient tolerance between different catheter sizes, we have been encouraged by how well our patients tolerated the No. 11 CAEC. An added benefit is that patients are able to vocalize while it remains in the trachea.

Placement of the No. 11 CAEC during a trial of tracheal extubation serves three purposes. First, it provides a means for the continuous administration of oxygen, which maintains the oxygen reservoir, allowing time to reestablish an airway if necessary. Second, it allows a means of securing the airway if indicated. Finally, it provides a method of ventilating the patient (jet ventilation) while the airway is being reestablished should tracheal reintubation prove complicated.

Use of tube changers to assist tracheal reintubation is not 100% successful nor is it without complication. Indeed, the CAEC was inadvertently removed from the trachea twice in this study of 40 patients. Care must be taken to avoid accidentally pulling the CAEC out when removing the existing ETT. Tracheal reintubation using the CAEC as a stylet may be more technically difficult in some patients. Although our data suggest the pediatric CAEC (No. 11) is rigid enough to facilitate tracheal reintubation, we caution that all patients’ tracheas may not be easily reintubated. We have found occasions when even a fiberoptic bronchoscope is not rigid enough to facilitate tracheal reintubation.

The tip of the ETT may “hang up” on the epiglottis or other soft-tissue structures of the larynx as it is advanced over the CAEC. If this problem occurs, forceful insertion of the ETT should be avoided to minimize trauma to vital airway structures and avoid kinking the CAEC. Gentle rotation of the ETT while trying to insert it may release the tip. Direct laryngoscopy may also relieve the obstruction and identify its cause. The airway can also be evaluated by placing a fiberoptic bronchoscope alongside the CAEC in an effort to determine the cause of resistance to ETT placement. Indeed, the CAEC can provide a useful guide to the trachea if fiberoptic intubation is eventually needed or if direct laryngoscopy is performed.

If tracheal reintubation using the CAEC is still not successful, the option exists to initiate jet ventilation. A CAEC was attached to a jet ventilator and test lung at the study institution. A drive pressure of 50 psi, tidal volume of 200 mL, and rate of 60 breaths/min delivered a 12-L/min ventilation. This was similar to that previously documented with another small jet stylet in an in vitro lung model.

Initially, concern was raised regarding potential complications from prolonged use of the CAEC, such as airway trauma or aspiration. A nonhollow tube changer had previously been left in place in a pediatric patient for a prolonged period (48 h) without complication. Aspiration risk was a concern for two reasons. First, by interfering with complete glottic closure, the CAEC poses a potential risk to an unprotected airway. Second, the CAEC could be mistaken for an orogastric or nasogastric drainage tube. All the patients in our study were kept nil per os, and the CAEC was clearly labeled to minimize these risks. None of the patients aspirated or had evidence of trauma to the airway.

The CAEC was left in the trachea for a minimum of 4 h. In a study of patients requiring tracheal reintubation, 87% (34/39 patients) required reintubation within the first 4 h following extubation. In our series, one patient required reintubation within 4 h; two reintubations occurred within 4 to 6 h; and the other took place 48 h following tracheal extubation.

Patients expected to have a difficult airway may remain intubated longer than necessary, simply for fear of the inability to reintubate. In one study, 50% of patients with unplanned tracheal extubations did not require reintubation, which was particularly true for postoperative patients. In patients who meet extubation criteria, use of the CAEC may allow safe assessment of the adequacy of the airway and an earlier trial of extubation without assuming increased risk.
Prolonged tracheal intubation not only increases the risk of complications, but it is expensive because it requires respiratory therapy and more extensive monitoring. Use of the CAEC for patients with a difficult airway might produce cost savings by demonstrating that patients will tolerate tracheal extubation earlier. This technique may reduce costs in other ways as well. Upon tracheal extubation, supplemental oxygen is usually administered via facemask or nasal cannula. Twenty-eight of 40 patients (70%) did not require oxygen administration by facemask or nasal cannula after the CAEC was removed. Our study demonstrates that this additional equipment may not be needed if oxygen is insufflated through the CAEC.

Prior to this study, tracheal extubation of patients suspected to be difficult for reintubation was managed in several ways at our institution. All airway equipment necessary for tracheal reintubation, including the fiberoptic bronchoscope, cricothyroidotomy kit, tracheostomy tray, as well as an assortment of ETTs, were assembled at the bedside. Then the trachea was extubated. In some “high-risk” individuals, an elective tracheostomy was performed. During the 1-year period of the present study, no airway emergency (defined as the inability to oxygenate the patient) occurred following tracheal extubation over the CAEC. When respiratory distress did occur, insufflation of oxygen through the CAEC allowed time to resecure the airway without oxygen desaturation. Hence, the CAEC provides a means of ensuring oxygenation, if not ventilation, while the airway is resecured following tracheal extubation. The CAEC facilitates reintubation when it is necessary and, therefore, allows a safer trial of tracheal extubation. This is reassuring given the absence of criteria to predict airway compromise following removal of the ETT. As with any airway technique, clinicians who employ jet-stylets or hollow tube exchangers should be familiar with the equipment, the potential complications, and other alternatives should difficulties arise. Direct laryngoscopy, cricothyroidotomy, jet ventilation, and fiberoptic equipment should be available as alternatives in the unlikely event that tracheal reintubation over the CAEC is not possible.

REFERENCES
3 Bedger RC Jr, Chang JL. A jet-stylet endotracheal catheter for difficult airway management. Anesthesiology 1987; 66: 221-23
9 Tahvanainen J, Salmenspera M, Nikki P. Extubation criteria from weaning from intermittent mandatory ventilation and continuous positive airway pressure. Crit Care Med 1985; 11:702-06
18 Watson CB. Use of fiberoptic bronchoscope to change endotracheal tube endored. Anesthesiology 1981; 55:476-77
21 Benumof JL. Management of the difficult adult airway with special emphasis on awake tracheal intubation. Anesthesiology 1991; 75:1067-1110