

## Brief review: Supplementing oxygen through an airway exchange catheter: efficacy, complications, and recommendations

## Article de synthèse court : L'administration d'oxygène par échangeur de sonde : efficacité, complications et recommandations

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### Abstract

**Purpose** An airway exchange catheter (AEC) may be employed as a conduit for endotracheal tube placement and for oxygen insufflation or jet ventilation via its lumen. The recent barotrauma-related death of a young healthy patient receiving oxygen insufflated through an AEC prompted the Chief Coroner of Ontario to seek guidelines regarding their use. A literature search was undertaken using a number of search strategies to investigate both the efficacy and complications associated with supplying oxygen through an AEC.

**Principal findings** No studies were found comparing either oxygen insufflation or jet-ventilation through an AEC to any standard forms of oxygen therapy. The only case series found using AEC jet ventilation reported that 11% of patients sustained pulmonary barotrauma. Thirteen case reports documented jet ventilation as being associated with pneumothorax, pneumomediastinum, pneumoperitoneum, cardiovascular collapse, and death. In three case series (totalling 76 adults and 20 children) using only oxygen insufflation, no complications were reported.

**Conclusions** Jet ventilation through an AEC may be associated with a significant risk of barotrauma. Oxygen insufflation appears to be associated with a lower risk, but

it is not risk-free. The authors caution against the use of an AEC to administer oxygen failing the proven benefit of its use over the use of standard oxygen therapies. Should a patient decompensate with an AEC in situ, tracheal re-intubation is the key management strategy. Supplemental oxygen can be provided using standard techniques prior to tracheal intubation or between attempts. Under emergency circumstances, oxygen insufflation or manual ventilation through an AEC may be considered provided vigilance for barotrauma is maintained and re-intubation is not delayed.

### Résumé

**Objectif** Un échangeur de sonde (AEC) peut être utilisé comme conduit pour positionner une sonde endotrachéale ou pour insuffler de l'oxygène ou de la ventilation en jet par sa lumière. La mort récente, liée à un barotraumatisme, d'un jeune patient en bonne santé recevant de l'oxygène insufflé via un échangeur de sonde a incité le coroner en chef de l'Ontario à demander l'élaboration de directives concernant son utilisation. Une recherche de la littérature a été entreprise à l'aide de plusieurs stratégies de recherche afin d'évaluer l'efficacité et les complications associées à la fourniture d'oxygène via un échangeur de sonde.

**Constatations principales** Aucune étude comparant l'insufflation d'oxygène ou la ventilation en jet via un échangeur de sonde à toute méthode standard d'administration d'oxygène n'a été trouvée. L'unique série de cas portant sur l'utilisation d'un échangeur de sonde pour la ventilation en jet a rapporté un barotraumatisme pulmonaire chez 11% des patients. Treize présentations de cas ont décrit la ventilation en jet comme étant associée à des cas de pneumothorax, de pneumomédiastin, de pneumopéritoine, de défaillance cardiovasculaire et de décès. Dans trois séries de cas (pour un total de 76 adultes et

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20 enfants) n'ayant recours qu'à une insufflation d'oxygène, aucune complication n'a été rapportée.

**Conclusion** *L'utilisation d'un échangeur de sonde pour la ventilation en jet pourrait être associée à un risque considérable de barotraumatisme. L'insufflation d'oxygène semble être associée à un risque plus faible, mais elle n'est pas sans risque. Les auteurs émettent une mise en garde concernant les échangeurs de sonde pour administrer de l'oxygène étant donné l'absence de bienfait avéré par rapport aux autres méthodes standard d'administration de l'oxygène. En cas de décompensation d'un patient avec un échangeur de sonde en place, la réintubation trachéale constitue la principale stratégie de prise en charge. L'oxygène supplémentaire peut être administré à l'aide de techniques standard avant l'intubation trachéale ou entre les tentatives. Dans des situations d'urgence, l'insufflation d'oxygène ou la ventilation manuelle via un échangeur de sonde peut être envisagée si l'on reste vigilant pour prévenir tout barotraumatisme et que la réintubation n'est pas retardée.*

The airway exchange catheter (AEC) or “jet stylet” catheter has been described in the literature in various forms for decades. It is used in a variety of clinical circumstances, e.g., to aid endotracheal tube exchange in an anesthetized patient or to act as a conduit for re-intubation in an awake spontaneously breathing patient during a trial of extubation. Airway exchange catheters are used in a variety of clinical areas, including the operating room and the post-anesthetic or intensive care units. Oxygen can be administered through an AEC using either high-pressure or jet ventilation (usually 10–50 psi) or low-pressure variable-flow oxygen (usually 1–10 L·min<sup>-1</sup>).

The Chief Coroner for Ontario recently reported the death of a 22-yr-old male patient (American Society of Anesthesiologists physical status I) due to tension pneumothorax associated with the use of an AEC.<sup>1</sup> The patient had undergone maxillofacial surgery. Intermaxillary fixation with elastic traction was utilized, equivalent to the jaws being “wired shut”. On emergence from anesthesia, an AEC was placed through his nasoendotracheal tube. The nasoendotracheal tube was then removed, leaving the AEC in its place. In addition, a nasogastric tube was placed through the contralateral nostril. The patient was transferred to the postanesthesia care unit (PACU) with the AEC attached to low-pressure oxygen insufflated at a flow rate of 5 L·min<sup>-1</sup>. Jet ventilation or the provision of oxygen at high pressures was *not* used. Within minutes of arriving in the PACU, he complained of back pain, and he deteriorated rapidly into cardiopulmonary arrest. Although a needle thoracostomy was performed for a tension pneumothorax, the patient did not survive.

Although jet ventilation through an AEC has been described as potentially resulting in barotrauma, this unusual case of pulmonary barotrauma appeared to result from low-pressure oxygen insufflation alone. With this in mind, we sought to review the efficacy of oxygen supplementation through an AEC compared with oxygen administered by standard modes (e.g., face mask, nasal prongs, continuous positive airway pressure [CPAP], and bi-level positive airway pressure [BiPAP]) as well as the associated complications. This report does not address the utility of AECs for tracheal re-intubation.

### Search strategy

A literature review was undertaken seeking to determine the efficacy and complications of supplying oxygen through an AEC. Four separate databases were used in the search: MEDLINE®, Emtree (Embase™), HealthSTAR, and CINAHL®. Our strategy included reviewing all articles with the terms “airway exchange catheter” and/or “jet stylet” as keywords. These terms were also combined with the subject heading or keyword search (depending on the database) of “pneumothorax”, “barotrauma”, “lung injury”, and “volutrauma”. All retrieved articles were hand searched for further relevant references.

### Principal findings

The effectiveness of an AEC for oxygenation

In our search of the four separate databases, no randomized controlled trials were found comparing jet ventilation or oxygen insufflation through an AEC with standard modes of providing oxygen. Therefore, we could not determine the benefit of supplementing oxygen through an AEC vs other standard oxygen therapies.

Table 1 includes all identified case series reporting the use of oxygen through an AEC. In the reported series, oxygen supplementation through the AEC was *not* the primary study outcome; generally, it was the overall utility of maintaining tracheal access following extubation of patients who would be difficult to re-intubate. One larger case series reporting AEC use<sup>2</sup> was excluded because it made no mention of oxygen supplementation through the AEC.

### Oxygen insufflation

Oxygen insufflation at rates of 1–8 L·min<sup>-1</sup> was reported in two adult series totalling 76 patients.<sup>3,4</sup> In a further series of 20 pediatric patients, oxygen insufflation was used at a flow rate of 2–6 L·min<sup>-1</sup>.<sup>5</sup> Patients in all three series were

**Table 1** Case series reporting oxygen supplementation through an AEC

Author	Patient population	AEC used	Intervention	Results
Fayoux <sup>6</sup> 2009	11 infants < 97 days old, primary airway management device for oxygenation during laryngotracheal reconstruction	8Fr Cook	AEC inserted below the area of stenosis. Infants ventilated manually or with volume-controlled ventilation @ 7 mL·kg <sup>-1</sup> , 30–40 beats·min <sup>-1</sup> , I:E ratio 1:1.5	1/11 hypoxemia managed with emergency tracheotomy. No cases of barotrauma reported.
Wise-Faberowski <sup>5</sup> 2005	20 children in the PICU; extubation strategy	8Fr, 11Fr, or 14Fr Cook	All insufflated with 2–6 L·min <sup>-1</sup> oxygen	No cases of barotrauma or SpO <sub>2</sub> < 90% reported.
Dosemeçi <sup>3</sup> 2004	36 patients post major neck/maxillofacial surgery; extubation strategy	11Fr Cook	All insufflated with 1–2 L·min <sup>-1</sup> oxygen.	No cases of barotrauma reported.
Loudermilk <sup>4</sup> 1997	40 ICU patients; extubation strategy	11Fr Cook	All insufflated with 2–8 L·min <sup>-1</sup> oxygen.	No cases of barotrauma or SpO <sub>2</sub> < 90% reported.
Cooper <sup>7</sup> 1996	202 ICU and PACU patients; mainly as an extubation strategy	12Fr CardioMed	Some insufflated with oxygen; jet ventilation at 15–50 psi in 45 patients	5 of 45 (11%) jet-ventilated patients suffered barotrauma

AEC = airway exchange catheter; PACU = postanesthesia care unit; PICU = pediatric intensive care unit; ICU = intensive care unit; I:E = inspiration:expiration

breathing spontaneously, and where reported,<sup>4,5</sup> none suffered oxygen desaturation < 90%. No cases of barotrauma were reported despite the adult studies being conducted on postoperative patients with known upper airway swelling. In a separate pediatric case series of 11 infants less than 97 days old, Fayoux<sup>6</sup> reported using either manually-assisted or volume-controlled ventilation through an AEC during laryngotracheal stenosis surgery. One neonate became hypoxemic and required tracheotomy, but none suffered barotrauma.

#### Jet ventilation

In the only case series we found that made mention of jet ventilation through an AEC, Cooper<sup>7</sup> reported on 45 patients who received jet ventilation through a CardioMed endotracheal ventilation catheter (ETVC) (Lindsay, ON, Canada). Thirty of these patients were anesthetized and pharmacologically paralyzed for various surgical procedures involving the lower airway. No data were presented in the series regarding the efficacy of oxygenation or ventilation.

#### Complications associated with oxygen supplementation through an AEC

Table 2 includes a summary of the literature reporting complications associated with oxygen supplementation through an AEC. Barring one case series by Cooper,<sup>7</sup> most publications were in the form of case reports. In Cooper's case series,<sup>7</sup> barotrauma occurred in five of 45 patients (11%) who received jet ventilation using driving pressures of 15–50 psi. Although not mentioned directly in his article, the authors have confirmed with Dr. Cooper that all cases of barotrauma were pulmonary in origin (personal communication, 2011). A further thirteen cases of barotrauma were found associated with oxygenation through an AEC.<sup>8–14</sup> Sixteen (89%) of the 18 patients who sustained barotrauma or volutrauma had received jet ventilation. Of those jet ventilated, thirteen (81%) sustained pulmonary barotrauma; two patients suffered gastrointestinal barotrauma,<sup>10,12</sup> and one patient manifested pulmonary volutrauma.<sup>12</sup>

Barotrauma has been reported over a wide range of jet ventilation driving pressures, including pressures as low as 15 psi.<sup>7,9</sup>

Does pulmonary barotrauma occur in the setting of oxygen insufflation through AECs *without* jet ventilation? The case detailed in the Coroner's report<sup>1</sup> suggests the answer is *yes*. Two other case reports (included in Table 2) describe barotrauma without jet ventilation. In one case, oxygen insufflation through a misplaced esophageal AEC

**Table 2** AEC-associated barotrauma and volutrauma complications

Author	Patient/series	Paralyzed/ spontaneous ventilation	AEC used	Intervention	Complication(s)
Nunn <sup>14</sup> 2007	1 patient	Paralyzed	14Fr Cook	Jet ventilation 50 psi with "short inflation bursts"	Bilateral tension pneumothoraces within 6-8 minutes, cardiac arrest
Fetterman <sup>15</sup> 2006	1 patient	Spontaneous Ventilation	14Fr Cook (misplaced, in esophagus)	Oxygen insufflation	AEC noted to be in esophagus, gastric perforation
Chen <sup>16</sup> 2004	1 patient	Paralyzed	15Fr Portex	Manual ventilation	Right pneumothorax with subcutaneous emphysema
McDonald <sup>13</sup> 1997	1 patient	Paralyzed	19Fr Cook	50 psi, 1:3 I:E ratio	Right tension pneumothorax
Baraka <sup>8</sup> 1997	1 patient	Paralyzed	14Fr Cook	Jet ventilation 50 psi, I:E ratio of 1:3	Right tension pneumothorax within 1 minute; cardiac arrest
Cooper <sup>7</sup> 1996	5/45 patients	Paralyzed	12Fr CardioMed	Jet ventilation 15-50 psi, other settings not stated	Pulmonary interstitial emphysema or pneumothorax*
Cooper <sup>11</sup> 1994	1 patient	Paralyzed	12Fr CardioMed	Jet ventilation with 20 psi, 10 beats·min <sup>-1</sup> , and an I:E ratio of 1:5, 1 time of 1 second	Right Pneumothorax
Egol <sup>12</sup> 1985	3 patients	Patient 1: Unknown Patient 2: Spontaneous ventilation	Patient 1: 18Fr tracheal suctioning catheter Patient 2: Double-lumen nasogastric tube as a jet stylet	Patient 1: 50 psi, other settings not stated Patient 2: 20 psi, I:E ratio of 1:2	Patient 1: Right sided pneumothorax and pneumoperitoneum Patient 2: Profound hypotension every time he spoke in the PACU during jet ventilation. No signs of barotrauma on CXR.
Chang <sup>9</sup> 1980	3 patients	Patient 1: Unclear Patient 2 and 3: Spontaneous ventilation	Patient 3: Jetted through suction port of a bronchoscope	Patient 3: 40 psi, other settings not stated	Patient 3: Large pneumoperitoneum inhibiting ventilation without pneumothorax or pneumomediastinum. No evidence of bowel perforation on post-mortem exam.
Chang <sup>10</sup> 1978	1 patient	Patient 1: Unclear	3.5-mm pediatric chest tube used as a "jet catheter"	Patient 1: Jet ventilation 10-16 beats·min <sup>-1</sup> , 15 psi, I:E ratio not stated;	Patient 1: left-sided tension pneumothorax
		Patient 2 and 3: Unclear	3.5 ETT attached to a 14G catheter distally	Patients 2 and 3: jet ventilation, other settings not stated 50 psi "intermittent jet injection" for 45 min	Patients 2 and 3: 2 bilateral pneumothoraces, 1 death Severe gastrointestinal distension, hypoxemia

\* This information was not included in the original article but was obtained from Dr. Cooper via personal communication  
AEC = airway exchange catheter; PACU = postanesthesia care unit; CXR = chest x-ray; ETT = endotracheal tube; I:E = inspiration:expiration

led to gastric rupture within one hour of initiating therapy.<sup>15</sup> In the other case, manual ventilation through an AEC caused a pneumothorax.<sup>16</sup> Conversely, no patients suffered barotrauma in the abovementioned three case series involving 76 adult<sup>3,4</sup> and 20 pediatric spontaneously breathing patients<sup>5,6</sup> in whom oxygen insufflation was used at flow rates of 1–8 L·min<sup>-1</sup>. In Dosemeci's study,<sup>3</sup> 18 of 36 patients had an AEC placed in the contralateral nostril along with a nasogastric tube (similar to the case described by McCallum<sup>1</sup>) yet no patient suffered barotrauma. This result suggests a lesser risk of volutrauma or barotrauma during oxygen insufflation through an AEC compared to jet ventilation.

In a separate case report of a right tension pneumothorax in a patient using jet ventilation, Baraka suggested oxygen should be maintained through the AEC at a flow rate of no more than 1–2 L·min<sup>-1</sup>.<sup>8</sup> However, given the other cases reported and the one described in this communication, even this flow rate may not be innocuous; it does not take into account the issue of impaired exhalation of tidal volume nor is it based on evidence.

## Discussion

### Structure and function of airway exchange catheters

The primary role of an AEC is to act as a “place holder” to maintain tracheal access while one ETT is exchanged for another. This can occur either immediately (e.g., when a double-lumen tube is exchanged for a single-lumen ETT), or it can occur when there is a possibility that an ETT *may* need to be re-inserted after extubation, particularly when earlier the patient had been difficult to intubate (i.e., “trial of extubation”). On occasion, the AEC is used as a conduit to administer oxygen. When used to retain tracheal access upon extubation, an AEC of 11Fr or 14Fr diameter is well-tolerated in over 90% of awake adult patients,<sup>2</sup> as long as it is not advanced to or beyond the highly innervated carina (Fig. 1). Although appropriate for adult tube exchanges, the larger 19Fr Cook AEC is associated with a much higher rate of patient discomfort<sup>2</sup> and, as such, is used rarely in the “trial of extubation” scenario.

The most popular airway exchange catheters are made by Cook Medical (Bloomington, Indiana, [www.cookmedical.com](http://www.cookmedical.com)). Available in a variety of diameters and lengths (Table 3), they are hollow with two side ports proximal to the distal opening, which are designed to help prevent obstruction to oxygen insufflation or jet ventilation. Sizes 8Fr and 11Fr AECs are usually considered “pediatric” because of the minimum-sized ETT they can accommodate. Variations to the standard Cook AECs include longer stiffer AECs that are designed to facilitate double-lumen tube exchanges. The ETVC from CardioMed is available in a



**Fig. 1** An awake patient in the postanesthesia care unit with an 11Fr, 83-cm Cook airway exchange catheter (AEC) *in situ* following anterior cervical spine fusion. Note supplemental oxygen administration via face mask. In this case, the AEC is routed through the face mask and taped to both the mask and forehead. The patient is able to phonate and breathe easily. The patient granted consent for publication of the masked image file

single size. Both the Cook and CardioMed products are supplied with proximal connectors (e.g., Cook Medical's Rapi-Fit<sup>®</sup> adaptor) to allow the option of oxygenation through the catheter. Airway exchange catheters are also produced and marketed by other companies.

### Oxygen supplementation through an AEC

Oxygenation through an AEC usually occurs during one of two clinical scenarios: 1) Passage of the replacement ETT has failed during an ETT exchange or re-intubation facilitated by an AEC, and oxygen is jetted or insufflated pending a decision on how to proceed; or 2) A patient with a known or potentially difficult airway has been extubated over an AEC, and oxygen insufflation is performed electively through the catheter.

Oxygen supplementation is accomplished through the hollow lumen of an AEC via the supplied adapters (Fig. 2) in one of two ways:

- 1) Using low-pressure variable-flow oxygen at 1–15 L·min<sup>-1</sup>. This is associated with low driving pressures even at the higher range of flow. Oxygen delivery can be accomplished through the lumen of the AEC using the 15-mm Rapi-Fit adapter (Cook Medical, Bloomington, IN, USA) either by intermittent positive pressure ventilation or by continuous oxygen insufflation.



**Table 3** Common airway exchange catheter sizing

Cook critical care devices			
Catheter OD, Fr	Catheter length, cm	Catheter ID, mm	For replacement of ETT with ID, mm
8	45	1.6	≥3.0
11	83	2.3	≥4.0
14	83	3.0	≥5.0
19	83	3.4	≥7.0
11 (stiff)	100	2.3	≥4.0
14 (stiff)	100	3.0	≥5.0
CardioMed endotracheal ventilation catheter (ETVC)			
Catheter OD, mm	Catheter length, cm	For replacement of ETT with ID	
4	85	>5.0	

ETT = endotracheal tube; OD = outer diameter; ID = internal diameter



**Fig. 2** Rapi-Fit<sup>®</sup> adaptors fitting the proximal end of the Cook airway exchange catheter (AEC). The Cook AEC is packaged with the Luer-Lok<sup>®</sup> adaptor already attached for jet ventilation or oxygen insufflation. Alternatively, a standard 15-mm adaptor is also supplied for oxygen insufflation or positive pressure ventilation

- Using high-pressure oxygen or “jet-ventilation”, usually with a driving pressure of 15–50 psi utilizing the Luer-Lok<sup>®</sup> adaptor. Hospital pipeline oxygen is supplied at approximately 50 psi, which may be reduced using a variety of down-regulating devices. The oxygen flow produced depends on a complex dynamic interaction of several factors, including driving pressure, inspiratory time, lung compliance, AEC length, and lumen size.<sup>17</sup>

The product monograph regarding oxygenation through the Cook Medical AECs<sup>25</sup> includes the following statements:

- A ventilatory device may be used at any time during the ETT exchange procedure by utilizing the attached Rapi-Fit adaptor;
- Potential adverse events include barotrauma and perforation of the bronchi or lung parenchyma;

- To avoid barotrauma, ensure that the tip of the AEC is always above the carina, preferably by 2–3 cm;
- If a high-pressure oxygen source is used for insufflation (e.g., jet ventilator), begin at lower pressure and work up gradually. Rising chest wall, pulse oximetry, and oral air flow should be carefully monitored.

#### Mechanisms of barotrauma

Pulmonary barotrauma is a term well understood amongst medical professionals. Rapid or excessive application of positive pressure to the tracheobronchial tree, as may occur with mechanical or jet ventilation, can damage respiratory structures. The term “volutrauma” is a relative newcomer to the medical lexicon, having originated in the critical care literature in the early 1990s.<sup>18</sup> This distinct entity implies an overdistension of alveoli, which leads to alveolar injury, increased mean intrathoracic pressure, impeded venous return, and other adverse events. At some point, the increase in volume leads to an increase in pressure that may culminate in barotrauma and its pathophysiologic sequelae (e.g. tension pneumothorax, air embolism, and others).

More simply, while high pressure jet ventilation may cause “pure” barotrauma by direct damage to tissues,<sup>19</sup> under certain circumstances, low or moderate flow gas insufflation may lead initially to volutrauma and ultimately to barotrauma. Continuous gas insufflation into the tracheobronchial tree is particularly hazardous in the face of upper airway obstruction that may hinder egress of the insufflated gas volume. If the volume of exhaled gas is less than the volume of inhaled gas, whether the inspired gas is jetted or insufflated through an AEC will not determine whether volutrauma or barotrauma will occur, it will simply affect the timeline it takes to occur. Thus, jet

ventilation is *not* required for lethal barotrauma to occur while using an AEC.

### Use of the AEC for oxygenation: an historical perspective

The 1993 and 2003 American Society of Anesthesiologists Practice Guidelines for the Management of the Difficult Airway<sup>20,21</sup> suggested that an “intratracheal jet stylet” is useful in a difficult ventilation situation and be included in the contents of a difficult airway cart.

In the early 1990s, Benumof carried out much of the initial research regarding the use of the AEC for jet oxygenation using a mechanical lung model. Prior to the widespread use of the laryngeal mask airway as a rescue device, instead of moving directly to surgical airway, transtracheal and trans-laryngeal jet ventilation were investigated as a means to provide oxygenation and ventilation in the “can’t intubate, can’t ventilate” failed airway situation.

Research focused on measuring the inspiratory tidal volumes generated by jet ventilation through an AEC and varying factors, such as the driving pressure, insufflation time, stylet resistance, and “lung” compliance. Benumof *et al.* operated the mechanical lung model with a driving pressure of 50 psi and normal “lung” compliance, and they found that tidal volumes of 440–1,680 mL were produced in one *second* by varying the size of the AEC.<sup>17</sup> Entrainment of additional air around the AEC (the Venturi effect) was relatively non-contributory, as the AEC was placed well below the glottis.<sup>22</sup> Although Benumof originally advocated 50 psi when jetting through an AEC, he later revised this to start at a pressure of “less than 50 psi”.<sup>23</sup>

Benumof *et al.* used the mechanical lung model once again to study the influence of tracheal diameter.<sup>24</sup> They found that air-trapping took place consistently when the tracheal diameter was < 4.0–4.5 mm. As a mechanical model cannot account for soft tissue compliance, this “critical diameter” may vary with the unique compliance of the obstructing anatomy in an individual patient. Whether a patient is breathing spontaneously or is assisted, the exhaled tidal volume will escape using the path of least resistance - mainly around, and not through, the AEC. Therefore, the external diameter of the AEC will impact the airway diameter required for adequate expiration. As Benumof stated, “If the equivalent annular air exit space that surrounds the AEC is less than a 4-mm internal diameter ETT, ventilation will not be possible because exhalation time will become markedly prolonged.”<sup>22</sup>

Calculating inspired volumes produced with jet ventilation by determining and weighting several variables is only one side of the equation. In clinical practice, probably the most important aspect of the formula is to ensure that

inspiratory and expiratory volumes remain equal. Complete exhalation must occur before the next inspiratory cycle.<sup>14</sup> While clinically determining “complete exhalation” may seem straightforward on the surface, in reality, it is close to impossible, particularly in the setting of a patient not on a mechanical ventilator, i.e., the typical patient in whom an AEC is placed. Although the Cook Medical product insert for the AEC suggests careful monitoring of “rising chest wall, pulse oximetry, and oral air flow”,<sup>25</sup> equally or perhaps more important is observing the patient for a falling chest wall, which would reflect adequate exhalation. Candido<sup>19</sup> observed, “There is simply not any monitoring device that can quantify ventilation with any degree of certainty”.

Adding to this complexity is phonation; when an AEC is used during a trial of extubation, patients can and do speak with an AEC in place.<sup>7,12</sup> Benumof recommended that the patient *not* phonate if jet ventilation is required.<sup>22</sup> Since the glottic opening is the narrowest part of the airway,<sup>26</sup> any adduction of the vocal cords during jet ventilation could lead to air trapping and barotrauma. This issue was highlighted in a patient case report by Egol<sup>12</sup> in 1985. The patient had his jaws wired shut postoperatively after surgical reduction for prognathism. A nasogastric tube was intentionally placed nasotracheally to act as an AEC. Although the patient was stable, a “demonstration trial” of jet ventilation was undertaken in the PACU. The initial jet settings were 20 psi with an inspiration:expiration (I:E) ratio of 1:2. The patient remained comfortable “until he tried to talk”. Egol reported, “At that time, his mean arterial blood pressure fell rapidly to 30 mmHg, presumably due to closure of his vocal cords around the catheter.” A chest *x-ray* revealed no evidence of barotrauma.

Logically, if vocal cord adduction for brief periods of time during jet ventilation results in hypotension, then prolonged adduction, as in the setting of laryngospasm or other obstructing laryngeal pathology (e.g., significant edema), could also lead to volutrauma or barotrauma, even with low-flow insufflation. Unless the degree of auto-positive end-expiratory pressure (auto-PEEP) can be measured or the patient explicitly demonstrates respiratory distress or signs of increased intrathoracic pressure, gradually increasing intrathoracic pressure may go unnoticed until the patient suddenly deteriorates.

### Conclusion

There is no literature comparing either oxygen insufflation or jet-ventilation through an AEC to any standard oxygen delivery modalities. It follows that there is no evidence showing either jet-ventilation or oxygen insufflation via an AEC provides better oxygenation than that afforded by standard therapies.

As reflected by case series and reports, jet ventilation through an AEC over a wide range of driving pressures and clinical conditions appears to be associated with a clinically significant risk of barotrauma. Although there have been several cautionary editorials<sup>22,23,27</sup> regarding the need to assess the degree of airway patency around the AEC to allow for passive exhalation, this is very difficult to determine at the bedside. Similarly, cautions regarding the need for maintaining an AEC in the mid-tracheal position and initiating jet ventilation at lower driving pressures are also problematic; both circumstances have been associated with barotrauma. Oxygen insufflation through an AEC appears to be associated with a lower risk of volutrauma or barotrauma, but, as suggested by the case presented by the Ontario Coroner, it is not risk-free. Until there is proven benefit of supplying oxygen through an AEC vs standard oxygen therapies, the authors would caution against its routine use.

Should a patient with an AEC *in situ* decompensate, tracheal re-intubation is the key management strategy. Supplemental oxygen can be provided using standard techniques prior to intubation. Under emergency circumstances, oxygen insufflation or manual ventilation through an AEC may be considered provided vigilance for barotrauma is maintained and tracheal intubation is not delayed.

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