CORRESPONDENCE

Anesthesiology
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Jet Ventilation through Jet Stylets

To the Editor:—The case report by Baraka[1] of jet ventilation through an airway exchange catheter (Cook Critical Care, Bloomington, IL) complicated by tension pneumothorax and cardiac asystole highlights some of the serious dangers of jet ventilation. I would like to focus on three aspects of the case report. The lessons from these can be added to the recommendations made by Baraka at the end of his case report.

1. The patient was an apparently healthy individual. There was no mention of difficult mask ventilation or oxygenation, but laryngoscopy was difficult.

A healthy individual, after adequate preoxygenation, should be able to maintain an acceptable oxygen saturation during changing of an endotracheal tube (ETT) over a stylet. If there is doubt about the patient's ability to maintain oxygen saturation, preoxygenation and hyperventilation followed by a trial period of apnea while the original ETT is in place would be useful. Rapid desaturation (within 1 or 2 min) indicates reduced respiratory reserve. The need to change the ETT should be reviewed. If the ETT does need to be changed, a method of oxygenation during the procedure should be chosen.

2. The airway exchange catheter (AEC) was inserted until resistance was felt, and the resistance was assumed to be from the carina.

A more likely occurrence is that the AEC was in the right bronchus. The right lung was then exposed to the high-pressure jet of oxygen, and tension pneumothorax ensued. If jet ventilation is to be used, the tip of the jet stylet should preferably be in the mid trachea. This may be difficult to judge. Distance markings on the ETT and jet styler should be used to position the stylet at the end of the ETT. If the stylet is passed until resistance is felt beyond the end of the ETT, it should be withdrawn by at least 5 cm in an adult. During jet ventilation, the position (depth of insertion) of the jet stylet should be monitored because catheter migration may occur.

3. Jet ventilation was followed by incomplete deflation of the chest. Despite this, two further jet pulses were delivered.

Jet ventilation should be discontinued the moment there is incomplete chest deflation. In most cases, a rapid rate of jetting (*e.g.*, 10–20 jet pulses/min) would be unnecessary. One or two jet pulses per 30–60 s may be all that is necessary during the entire procedure.

Jet ventilation should be used with extreme caution because complications may be life-threatening. Documentation of rapid desaturation during apnea and failure to maintain oxygen saturation by oxygen insufflation is highly recommended before jet ventilation is used during changing of endotracheal tubes. The cardiovascular and respiratory systems should be closely monitored during and after the procedure, and there should be a high index of suspicion regarding the development of tension pneumothorax. Finally, it may be time to ensure that all jet injectors have pressure regulators. The use of lower jet pressures will not prevent barotrauma but may reduce its incidence.

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Revisiting the ASA Guidelines for Management of a Difficult Airway

To the Editor:—We read with great interest the case report by Baraka entitled "Tension Pneumothorax Complicating Jet Ventilation *via* a Cook Airway Exchange Catheter"[1] and the accompanying editorial view, "Airway Exchange Catheters: Simple Concept, Potentially Great Danger," by Benumof.[2] We agree with the authors as to the importance of airway exchange catheters (AECs) in airway management but wish to address the following issues.

1. the etiology of barotrauma

Barotrauma associated with the use of AECs has been reported as a result of direct trauma to the tracheobronchial tree by the catheter[3,4] and that caused by an increase in lung volume or pressure.[1] We would like to suggest the blast effect of air impacting on intact human tissue as a third possible etiologic factor. Figure 1 shows the effect of a force generated by applying 25 psi into the proximal part of a 3-mm ID AEC made by Cook Critical Care (Bloomington, IN). Although we found no documentation in the literature as to the effect of this high force on the trachea and bronchial tree, this cannot possibly be benign, especially when it is exerted on the bronchial tree or in a small-diameter airway with low run-off.

2. the safety of jet ventilation through an AEC

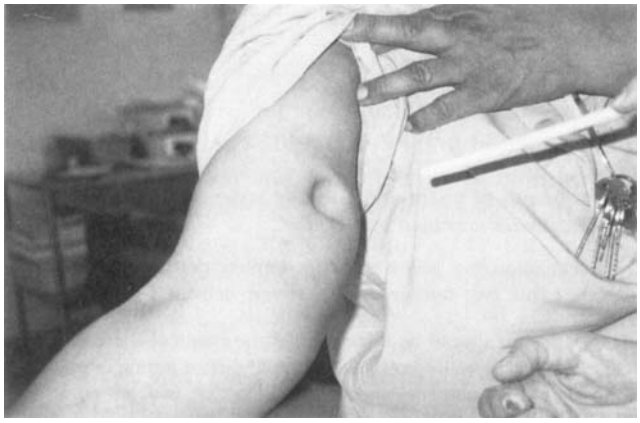

Fig. 1. Photograph of the blast effect of a jet stream impacting intact human tissue. Notice the tissue response to the enormous, uncontrolled force. Transmission of this considerable force, especially to the small-caliber airways, may have potentially devastating effects.

The guidelines proposed by Benumof[2] for the safe administration of jet ventilation through an AEC can be summarized by three major principles, including the limitation of a driving pressure to 25 psi, limiting inspiratory time to less than 1 s and ensuring an equivalent annular air exit of more than a 4-mm ID endotracheal tube.[5,6] The only relevant study in the literature reports the incidence of barotrauma when using a jet ventilation technique through an AEC as 11%.[7] We believe that this high complication rate is a function of several variables during jet ventilation. The three most important factors include static and dynamic compliances of the lung in varying states of health, unique physical properties of different AECs, and unpredictable effective flows in the jet system. Our current technology does not allow for predetermining jet ventilation variables (driving pressure, inspiratory time, and so forth). We simply are unable to deliver safe and effective ventilation through an AEC with use of a hand-controlled jet ventilation technique in light of these multiple factors. Also, there does not appear to be an appropriate monitoring device for qualifying or quantifying ventilation with any degree of certainty. The only method for evaluating the delivery of a tidal volume is a rudimentary visual observation of chest expansion.[1,7]

3. the acceptable complication rate for any medical procedure

There is no human study in the literature that evaluates jet ventilation with use of a hand-controlled interrupter valve *via* an AEC through an *in situ* endotracheal tube. The study by Cooper[7] reports 11% barotrauma when an AEC is used to provide jet ventilation in the absence of an endotracheal tube.

One must consider the clinical usefulness of any medical procedure associated with an 11% severe complication rate even for experienced users of the technique. We believe the anesthesiology community must be hard pressed to find alternative approaches or abandon altogether the use of jet ventilation through an AEC.

Finally, Benumof notes that "airway management options provided by an AEC are *extremely important* and are *well-recognized* by the American Society of Anesthesiologists"[2] (emphasis added). In the citation for Benumof's assertion,[8] the introductory statement is, "Practice guidelines are subject to revision from time to time, as warranted by the evolution of medical knowledge, technology and practice." Perhaps the time has come to revise the American Society of Anesthesiologists practice guidelines for management of the difficult airway.

Because jet ventilation should not be necessary during the brief period of time essential for tube exchange[1,7] and because both the risk and the severity of complications associated with jet ventilation through AEC is high, we believe the title of Benumof's letter should be more emphatic and should read "Prohibitive Dangers Associated with Jet Ventilation through These Catheters," instead of "Potentially Great Danger."

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In Reply:—The suggestion by Candido *et al.*[1] to change the words in the title of my editorial from "Potential Great Danger" to "Prohibitive Danger" is the result of a poor risk-benefit analysis. No one disputes the great benefit and small risk of having a stylet already *in situ* in the trachea should the planned or unplanned need for reintubation arise ("simple concept"). What is disputed is the risk-benefit of using the stylet for jet ventilation. The benefit of having a safe ventilatory and oxygenating mechanism already *in situ* in the trachea in case reintubation is unsuccessful is also obvious ("simple concept"). My editorial simply pointed out the many ways in which the risk of jet ventilation *can be* greatly increased and, conversely, the many ways in which the risk of jet ventilation *can be* greatly decreased. Therefore, if one jets with a 25-psi and 0.5-s inspiratory time through a relatively small airway exchange catheter (AEC) inserted no more than 26 cm in an adult, the ventilation risk is small. Figure 1 and the legend of figure 1 of the letter to the editor by Candido *et al.*, which shows some displacement of subcutaneous tissue caused by a sustained (?) 25-psi jet from a large AEC, is misleading because the arm is richly endowed with adipose tissue and the flows over a very short period of time from this system are well-known.[2] The tidal volume from a 25-psi, 0.5-s jet from a large AEC into a lung with static compliance of 50 ml/cm H_2O is approximately 350-400 ml.[2] The title of my editorial does not need to be changed; what needs to be changed is the mindset and knowledge of practitioners who use AECs about how to achieve the optimally low risk-benefit ratio of AECs.

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In Reply:—Thank you for referring to me the letters to the editor from R. P. Haridas and Kenneth D. Candido *et al.* regarding my manuscript, "Tension Pneumothorax as a Complication of Jet Ventilation *via* a Cook Airway Exchange Catheter."[1]

The patient described could easily receive ventilation by a face mask after induction of anesthesia and before laryngoscopy and tracheal intubation. The exchange catheter was advanced until resistance was felt; the airway exchange catheter might have wedged in the bronchus, obstructing the air escape. As recommended in the editorial view of Benumof[2] that accompanied the report, "A prudent rule to follow is never to allow the centimeter calibration on the AEC to exceed a depth of 26 cm in an adult and never to insert an AEC when resistance is encountered [to avoid tear beneath the trachea]."

The tension pneumothorax that developed in our patient may be secondary to barotrauma or a result of direct trauma to the tracheobronchial tree by the tip of the catheter or by the force generated by the jet *per se*. The case report [1] and the accompanying editorial view of Benumof[2] outlined the different precautions that may decrease the incidence of this serious complication, such as limiting the jet pressure and the inspiratory time. These parameters may be difficult to control with use of a hand-controlled jet ventilation technique. Automatic jet ventilation can be achieved by interrupting the pipeline oxygen (50-60 psi) by a Bird Ventilator Mark II (Bird Products Corp., Palm Spring, CA) or by a solenoid valve, which is electronically controlled;[3-5] the system controls both the inspiratory and the expiratory times, and the delivered pressure of the jet.

We have used automatic jet ventilation safely in children anesthetized by the T-piece circuit[3] or undergoing rigid bronchoscopy. Also, the technique was used in adults undergoing airway surgery.[4,5] In all these situations, the jet is delivered *via* the anesthesia circuit, the bronchoscope, or the endotracheal tube, not directly by a catheter placed in the tracheobronchial tree. This may attenuate the jet and does not interfere with the air exit during passive exhalation.

Barotrauma may be more frequent[6] when the oxygen jets are delivered by an exchange catheter directly into the tracheobronchial tree. Because of the "prohibitive dangers associated with jet ventilation