Letters

Bilateral tension pneumothorax during jet ventilation

To the Editor:

Those who do not remember the past are doomed to repeat it. —George Santayana

We read with much interest the recent case report in the *AANA Journal* titled "Bilateral tension pneumothorax during jet ventilation: A case report" (2000;68:241-244), authored by Mary Jo Hardy, CRNA, MSN; Craig Huard, CRNA, MSN; and Thomas C. Lundblad, CRNA, MSN. Unfortunately, in this case, it appears that Santayana's admonition was disregarded with respect to the safe utilization of jet ventilation (JV). Despite recognition in the literature of the potential dangers of hand held demand valve insufflators extending back as far as the technique's introduction in 1967, incidents of barotrauma continue to occur and are reported as if they are both new and surprising.[1-10] With this in mind, we hope to offer some constructive comments based upon the literature and our own clinical experiences utilizing JV under a wide array of circumstances. Our remarks focus on the areas of inspiratory pressure, outflow obstruction, diligence, and the potential application of high frequency jet ventilation (HFJV).

Pressure

In JV, the high "driving pressure" is used to overcome the resistance of the small delivery cannula to achieve normal tidal volume. Peak airway pressure is directly proportional to the tidal volume given. Every second at least 500 mL of gas will be delivered. It is imperative that the anesthesia provider be aware of the dangers of introducing high pressure (and therefore high flow/volume) ventilations when using any form of hand controlled flow interrupter valve. By prolonging inspiration for just 1 second, an additional 500 mL of gas could be added to the lungs. A reducing regulator must be in line to decrease pressure from the usual 50 psi delivered from the wall source or the potentially higher pressures of a cylinder source.[11] Initiation of JV with such high set driving pressures, even in the presence of an anatomically normal tracheobronchial tree and/or normal lung parenchyma, is an invitation for barotrauma to occur due to excessive tidal volume.

Hardy and associates describe JV as having insufflation pressures less than 50 psi, a rate of 10 to 12 breaths per minute, and an inspiration time of 1 to 2 seconds. While technically a correct definition, we believe that ventilations should always begin at a lower psi setting and be gradually increased based upon visible chest excursion, breath sounds via precordial stethoscope, audible exhalation, and vital sign monitoring. It also is unclear at what driving pressure JV was initiated in this case report. Benumof recommends starting at 25 psi and an inspiratory time of less than 1 second during the use of airway exchange catheters.[10,12] Our preference during the initiation of any form of JV is to begin at an even lower pressure (no higher than 20 psi) and to adjust upward to obtain adequate ventilation.

Outflow obstruction

Numerous case studies in the literature point to outflow obstruction as the key element in barotrauma.[1-3,5,6,8,10] One omission in this current report is that while a general overview of potential etiologies was given, no speculation was made as to the cause of the barotrauma. Additionally, crucial pieces of information that could have provided some clues, such as the placement of the delivery device (above the glottic opening or below the vocal cords?) and the approximate inspiratory/expiratory ratio, were omitted. As such, we can give no specific recommendations to this case but can offer general guidelines.

We concur with the authors that a thorough preoperative assessment of the airway is necessary. This should ideally be done in conjunction with the surgical team. The potential role of obstructive lesions and the type of instrumentation to be utilized needs to be clearly defined. Outside of laryngoscopy, there have been descriptions of a wide array of implements for the delivery of JV (ie, through the suction port of a fiberoptic bronchoscope, rigid bronchoscopes, airway exchange catheters, insufflation catheters, and transtracheal ventilation). The space available around the instrumentation for exhalation is crucial, and several sources give some parameters to guide the judicious use of airway instrumentation in the setting of JV.[10,12]

Other underlying pathology also should be seriously considered. Pulmonary function testing was not indicated as being available for this case report. The authors mention the patient's significant smoking history and later discuss the concept that emphysema/chronic obstructive pulmonary disease could reduce the passive recoil necessary for exhalation.[13] They do not, however, definitively make that connection with this patient whose smoking history would lead to the suspicion of chronic obstructive pulmonary disease. In effect, this patient could have had a "parenchymal" outflow obstruction suggesting the need for extended exhalation times. Inspiratory times should certainly have been kept below 1 second, and it is not clear from the description of methods whether this did occur.

Diligence and communication

As Hardy and associates have demonstrated and as numerous case reports have indicated, barotrauma in the

setting of JV can occur rapidly, sometimes with the application of a single insufflation. As this article described, breaks in the airway mucosa can provide conduits for potential subcutaneous emphysema and/or pneumothorax. During those procedures where the anesthesia and surgical teams share the airway, such as laryngoscopy, constant communication between the surgical and anesthesia teams is vitally important so that the emergence of any potential obstructions or lacerations can be dealt with effectively.

We advocate that whenever JV is administered via a hand controlled flow interrupter system that one anesthesia provider be exclusively dedicated to this task. Given the potential for rapid changes in airway inflow and outflow dynamics, it is unlikely that one provider can safely attend to the complex ventilation needs, as well as the other anesthetic needs of the patient.

High frequency jet ventilation

The Hardy et al case study proposes several alternatives for safer practices, which we feel do not adequately address several critical issues with respect to safe JV. While we certainly applaud the authors' call for vigilance and preparation, we felt that their suggestions for greater safety during JV were very generic. We also would question the recommendation to monitor end tidal carbon dioxide ($ETCO_2$) as a primary method to detect pneumothorax during JV. It is our opinion that the use of an $ETCO_2$ monitor during JV will not be sensitive in the detection of pneumothorax because $ETCO_2$ monitoring during JV typically lacks the ability to quantify CO_2 reliably. In addition, the use of laser or electrocautery in the airway could produce combustion products that result in fluctuations of the CO_2 level. In summary, $ETCO_2$ monitoring during JV is likely to be a very insensitive indicator of tension pneumothorax.

In actuality, the key safety concern highlighted by the unfortunate outcome reported by the authors involves the risks of using a hand held jet insufflator for an elective procedure. We have long believed that when JV is indicated in an elective case, practitioners should select the use of HFJV as the preferred mode. Introduced in 1977, HFJV has a proven track record of ventilatory efficacy and safety.[14,15] Ironically, its use in the treatment of disruptions of the airway, including pneumothorax, is also well documented.[16] In addition, it has been shown that if the frequency does not go below 60 breaths per minute and inspiratory/expiratory ratio is at least 33%, HFJV will prevent aspiration.[17,18] It also has been successfully used in the presence of airway obstruction[19,20] and in patients with unique surgical/anesthetic needs.[21]

With regard to barotrauma, the primary issue in this case, a modern high frequency jet ventilator incorporating end expiratory pressure monitoring into the array of functions provides an adjustable but nondefeatable alarm that interrupts the delivery of gas when the set pressure limits are exceeded. We begin with a peak end expiratory pressure setting of 20 cm H_2O but may adjust downward based on clinical indicators. While we do not claim that this will eliminate all incidence of barotrauma, it provides a measure of safety not attainable by any provider delivered hand ventilation device.

Additionally, ventilatory rate and inspiratory/expiratory ratios are precisely controlled, a crucial factor in the type of case presented by Hardy and associates. We have utilized this mode of ventilation across a wide spectrum of intraoperative applications, accumulating a database of more than 1,500 cases with only 3 known instances of barotrauma from 1985 to 1995. In addition, we routinely monitor $ETCO_2$ during HFJV as a correlative monitor for evaluation of ongoing ventilation. We strongly advocate the use of HFJV in place of JV via demand valve with the notable exception of the true airway emergency when a high frequency ventilator may not be readily available. Even then a higher respiratory rate of at least 20 breaths per minute with small tidal volumes (inspiration time of 1 second or less) should be used.

Conclusion

Jet ventilation is a powerful tool in the armament of airway management, assuming that the practitioner is familiar with all of the potential applications, as well as the potential risks. Using HFJV delivered with a modern automatic jet ventilator incorporating proper safety features can successfully prevent most of the dangers. We encourage practitioners to become fully informed about this modality, especially HFJV, to review the literature carefully prior to utilizing the technology, and to plan appropriately before clinical application of these techniques. Otherwise we truly are doomed to repeat our collective past mistakes.

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Editor's Note

The original authors (Mary Jo Hardy, Craig Huard, and Thomas C. Lundblad) declined the opportunity to respond to the above letter. In the case report presented by Hardy and associates, the jet ventilator was positioned infra-glottically, and the inspiratory time was 1 to 2 seconds in accordance with chest rise at a rate of 16 times per minute.