Manual Ventilation and Risk of Barotrauma: *Primum Non Nocere*

Optimizing bag ventilation during cardiopulmonary resuscitation or ventilation of an unprotected airway[1] is mandatory to minimize the risk of pulmonary complications and the occurrence of gastric inflation due to excessive airway pressure.[2] Numerous studies have underlined the difficulty of providing safe and effective bag ventilation in these situations, and new devices have been marketed to help clinicians ensure adequate ventilation.[3,4]

During bag ventilation of an intubated patient, the risk of excessive airway pressure is even greater, because of the absence of air leak. Several case reports have told of complications associated with bag ventilation, including lung hyperinflation resulting in electromechanical dissociation[5] and severe pulmonary barotrauma.[6–8] It appears that some of these incidents were due to the malfunction or misuse of the bag-valve device, whereas in other instances the pattern of ventilation was clearly responsible for the incident. Little is known about the risk of barotrauma during bag ventilation of intubated patients, although situations that require bag ventilation are frequent (eg, manual ventilation after tracheal intubation before connecting the patient to the ventilator, during intrahospital transport, or sometimes because of persistent desaturation despite having increased the fraction of inspired oxygen [F_{IO_2}] during acute respiratory failure).

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Although there are abundant data in the literature regarding manual hyperinflation as a technique to enhance secretion clearance and to re-expand areas of atelectasis,[9] less attention has been given to the ventilation patterns provided during manual ventilation in urgent situations. Nonetheless, because manual ventilation is relatively unconstrained, ventilation patterns differ significantly among clinicians,[10] and certain manual ventilation patterns could be inappropriate and deleterious in certain circumstances. A better understanding of ventilation patterns during manual ventilation may help reduce differences in bag-ventilation technique among care providers and thus reduce the risk of adverse effects with this universal technique.

In this issue of RESPIRATORY CARE, Turki et al elegantly investigate the ventilation patterns provided by different respiratory therapists during manual ventilation.[11] Using a test lung model (with which the resistance and compliance can be set), Turki et al conducted 2 distinct experiments. The first one recorded peak airway pressure (P_{peak}), tidal volume (V_T), and respiratory frequency during manual ventilation with varying load conditions, and the second recorded those same variables during manual ventilation in 3 clinical scenarios illustrating the different load conditions tested initially. They report that in both experiments, although all 3 of the variables varied considerably among the respiratory therapists who participated in the study (eg, V_T ranged from 400 mL to > 1,000 mL), P_{peak} was the only variable to differ significantly from one load condition to another. Importantly, some therapists delivered pressures exceeding 100 cm H_2O. These very high pressures were encountered in the high-resistance/low-compliance scenario, resulting, however, in smaller V_T than in the normal-resistance/low-compliance scenario. Interestingly, the frequency during bag ventilation was relatively high (approximately 25 breaths/min) and very similar in the 3 situations, indicating that the risk of dynamic hyperinflation in the high-resistance scenarios was not taken into account.

How do the results from Turki et al compare with existing literature? Clarke et al examined ventilation characteristics in mechanically ventilated patients during manual hyperventilation for chest physiotherapy,[12] and the mean delivered V_T was 170% of the V_T delivered before chest physiotherapy. The maximum V_T range was 838–1,674 mL, which negatively correlated with the patient's lung injury score. The average peak inflation pressure range was 37–74 cm H_2O.

It is beyond the scope of this editorial to debate on the benefit of manual hyperinflation during mechanical ventilation (although one must bear in mind that its effect on outcome remains unproven), but values found by Clarke et al[12] during manual hyperinflation of intubated patients are in the range of those found by Turki et al[11] with their test lung. It is difficult to conclude from these studies whether the manual ventilation patterns impact the occurrence of barotrauma, but the values measured by Turki et al are unnecessarily high and would clearly put patients at risk of lung overdistention. The question then arises, how to avoid these potentially deleterious patterns? The results from Turki et al indicate that it may not be sufficient merely to provide relevant clinical information that should enable the clinician to approximate the patient's respiratory mechanics and thereby adapt the manual ventilation pattern to the patient's condition. A direct feedback mechanism that would immediately indicate to the clinician what he or she is actually doing could help in adjusting bag-ventilation technique. Such feedback can be provided by a pressure manometer mounted on the bag. Although P_{peak} and risk of barotrauma are not necessarily directly linked (see below), use of a pressure manometer increases accuracy and reduces variability of manual ventilation.[13]

In order to interpret these data and their potential relevance for the risk of barotrauma during manual ventilation, one must bear in mind the following points:

First, barotrauma (better termed extra-alveolar air) most often results from overdistention and rupture of alveoli walls, down a pressure gradient from air space into the bronchovascular sheath.[14] This finding indicates that it is not high airway pressure *per se* that ruptures alveolar walls. Unfortunately, researchers who tried to link ventilation settings and resulting pressures to the occurrence of barotrauma very often measured peak inspiratory pressure, which poorly reflects transalveolar pressure. Thus, although some studies have indeed found that high P_{peak} occurs in patients who also develop barotrauma,[15–17] no definite causal relationship has been demonstrated with high P_{peak}, whereas end-inspiratory (plateau) pressure (which better approximates transalveolar pressure than does P_{peak}) was recently found to be associated with the risk of barotrauma.[18]

Second, several studies have clearly shown that the underlying lung disease (such as chronic interstitial lung disease and acute respiratory distress syndrome) is also a major condition for the development of barotrauma during mechanical ventilation.[17,19] This clearly indicates the necessity of providing relevant clinical information to the clinician who is bag-ventilating a patient in an emergency situation, although that information may be insufficient, as illustrated by the results from Turki et al. Incentive feedback on the way the ventilation is conducted should further help avoid potentially deleterious ventilation patterns.

Finally, the results from Turki et al suggest that care providers should train with a test lung, to help them realize the ventilation patterns they may generate during manual ventilation.

With manual ventilation, as with any medical treatment, even in life threatening situations, *primum non nocere*.

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