

## Performance of Transport Ventilators

The paper by Chipman et al in the June 2007 issue of *RESPIRATORY CARE* represented a monumental undertaking to evaluate 15 transport ventilators.<sup>1</sup> We reviewed the paper on several occasions to reconcile their findings with our work on transport ventilators.<sup>2-9</sup> We write to point out several inaccuracies in the study and ask Chipman et al to more clearly explain their findings and recommendations.

In their Table 1, Chipman et al list the positive end-expiratory pressure (PEEP) of the LTV1000 as 0–30 cm H<sub>2</sub>O. The actual range is 0–20 cm H<sub>2</sub>O. The table also lists the PEEP of the Crossvent 3 as 0 cm H<sub>2</sub>O, but the Crossvent 3 is capable of PEEP up to 35 cm H<sub>2</sub>O. Were Chipman et al referring to an earlier model of the Crossvent 3 that couldn't supply PEEP? Also, the Vortran is listed as being capable of providing continuous mandatory ventilation (CMV) and intermittent mandatory ventilation (IMV), but in fact the Vortran can provide only pressure-cycled CMV. Similarly, the Percussionaire TXP provides only IMV, not CMV. With the Percussionaire TXP, if the patient breathes spontaneously, air is entrained from the inspiratory port of the Phasitron.

We are unclear as to why Chipman et al listed both assist-control and CMV for some ventilators, as those 2 modes are the same. Did they mean to distinguish between ventilators that can be patient-triggered and those that can deliver only mandatory breaths? If so, then errors still remain. The PneuPac ParaPac ventilators have a mode termed SMMV (synchronized minimum mandatory volume), not MMV (mandatory minute volume) or IMV, which are quite different, in that if the patient breathes spontaneously at a respiratory rate equal to or greater than the set rate, the ventilator does not provide any mandatory breaths.

Also the Crossvent 3 has a selection for pressure support but does not have the ability to flow cycle. This mode results in patient-triggered, pressure-limited, time-cycled support. The Crossvent 3 is listed as having both volume and pressure control, but in fact it is capable of only pressure-

limited ventilation via a mechanical pressure-relief valve. In that instance the ventilator continues to deliver the set flow and volume according to the volume control settings, but vents gas to the atmosphere if the pressure threshold is reached. These errors may have resulted from Chipman et al depending on the manufacturer's literature for their data. However, since their intention was to compare available devices, we believe these errors should be pointed out so readers can determine the actual performance of the devices, not simply mimic the manufacturer's specifications.

Chipman et al stated that in their bench protocol the Impact/Uni-Vent Eagle 754 operated on an E-size cylinder for 35 min, which is substantially less than we have observed and is not consistent with that ventilator's function.<sup>2</sup> Was this test repeated more than once? This finding suggests either a leak in the system, a malfunctioning ventilator, or unfamiliarity by the operator. Was the tidal volume ( $V_T$ ) continuously measured to assure that the correct minute volume was being delivered? As Chipman et al are well aware from their experience, repetition of laboratory experiments is invaluable in the detection of one-time errors.

In Table 2, Chipman et al concluded that neither the Impact/Uni-Vent Eagle 754 nor the Pulmonetic LTV1000 are capable of ventilating injured lungs. As in our previous comment, that conclusion is inconsistent with the bench data and the worldwide experience with those 2 devices. For over a decade the Impact/Uni-Vent Eagle 754 has been successfully used to transport critically ill soldiers (including many with acute respiratory distress syndrome) between military care centers. Similarly, the LTV1000 is capable of volume and pressure control at up to 80 breaths/min, and is used by many centers for transport of critically ill patients. We request that Chipman et al explain the nature of the failures with the Impact/Uni-Vent Eagle 754 and the Pulmonetic LTV1000, and reconcile their findings with the common experience.

Our review of the animal-model experiments in the Chipman et al study led us to understand that a single animal was used to test 5 separate ventilators, in random sequence. Is it possible that the small number

of animals resulted in a ventilator being disadvantaged in the trial because of the sequence? As an example, Figure 2 indicates that each ventilator was used in 2 animal experiments. What was the progression of the lung injury? If the first 4 ventilators failed to provide adequate oxygenation or ventilation, would that worsen the lung injury and thus make the fifth ventilator fail to provide adequate gas exchange? Does their surfactant-wash-out model improve with time, or does gas exchange steadily worsen? Also, the performance of every ventilator is affected by the device characteristics, the condition of the animal, and the understanding of the operator. It seems incongruent that a given ventilator is capable of maintaining gas exchange in one animal, but not the other, unless the ventilator model is substantially different or the operator fails to make the appropriate changes.

Finally, though Chipman et al concluded that the Impact/Uni-Vent Eagle 754 is unable to ventilate injured lungs, it is one of the ventilators they recommend in their conclusions. Though we agree, and experience clearly demonstrates that this recommendation makes sense, how did they come to this conclusion? At the end of their exhaustive study, how did Chipman et al determine which ventilators to recommend? Were characteristics ranked or weighted? Was each ventilator given a score for performance in each of the evaluations? Though we agree that both the Impact/Uni-Vent Eagle 754 and Newport HT50 meet the requirements for a "front-line ventilator for rescue situations," we are not sure why the LTV1000 and VersaMed iVent do not.<sup>10</sup> Did Chipman et al eliminate the LTV1000 because of its high gas consumption? Was the VersaMed eliminated because of short battery life and excessive weight? We request that Chipman et al describe the system they used to come to their conclusions. If gas consumption, size, and battery life were the only factors considered, the animal experiments seem unnecessary.

We appreciate the substantial effort by Chipman et al in this project and their commitment to provide the respiratory care community with much-needed data. However, we believe they should correct some errors and explain the findings that seem to run

counter to our experience and common sense.

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#### *The authors respond:*

We thank Branson and Rodriquez for their letter.<sup>1</sup> We agree there were mistakes in one of our tables that we missed during editing, and that there is considerable disagreement about terminology. However, we also believe that most of the issues they raise were covered in the paper.

Branson and Rodriquez are correct that the positive end-expiratory pressure (PEEP) ranges for the Pulmonetic LTV1000 and Crossvent 3 are 0–20 cm H<sub>2</sub>O and 0–35 cm H<sub>2</sub>O, respectively, and we thank them for pointing this out. We do, however, take exception to what they describe as inaccuracies with respect to various ventilation modes.

It is unfortunate that no standardized nomenclature exists for classifying ventilation modes. Ventilator manufacturers use various names to describe their devices' modes. Consider 2 commonly used ventilators, the Puritan Bennett 840 and the Dräger Evita 4. The Evita 4 offers a continuous-mandatory-ventilation mode that allows timed or patient triggering of constant-volume breath delivery, as well as the PCV + Assist mode that allows timed or patient triggering of pressure-controlled breaths.<sup>2</sup> Both of those modes may be defined as a form of assist/control ventilation (ie, all breaths are delivered by the ventilator at a set minimum rate [mechanical breaths], but the patient may trigger the ventilator and thus cause a rate greater than the set rate).<sup>3</sup> Contrast this to controlled mechanical ventilation, in which all breaths are delivered by the ventilator at a set rate and patient triggering is not allowed.

With the Puritan Bennett 840 the clinician must first select a ventilation mode, and we will again use the example of assist/control, followed by the selection of a mandatory breath type, such as volume control or pressure control.<sup>4</sup>

In the neonatal arena, the Dräger Babylog has a mode in which the ventilator delivers a set number of non-synchronized, time-cycled, pressure-limited breaths, and the patient is allowed to breath spontaneously in between the breaths from a clinician-adjustable, continuous gas flow. Although we have known this ventilation mode for many years as intermittent mandatory ventilation (IMV), on the ventilator the manufacturer describes it as CMV.<sup>5</sup>

We did not evaluate any of these ventilators during spontaneous ventilation, which we clearly identified as a major limitation of our study. Consequently, we relied on the manufacturers' documentation regarding triggering and spontaneous breathing capabilities.

Several years ago, Chatburn and Primiano, in an attempt to promote standardization of nomenclature, published an extensive description of ventilation modes.<sup>6</sup> However, no consensus on the use of that nomenclature has been established. Neither the engineers who design ventilators, the marketing and sales people, nor clinicians use Chatburn and Primiano's nomenclature. In the absence of such consensus, it has been our practice to describe ventilation modes as controlled, assist/control, synchronized intermittent mandatory ventilation (SIMV), or spontaneous, and the breath-delivery types as volume-controlled, pressure-controlled and/or pressure-supported. In our paper we intentionally disregarded the manufacturers' descriptions of modes and applied the above classification system. Thus, since the Percussionaire delivers a set number of mechanical breaths to a patient making no spontaneous respiratory efforts, it was classified as