

Commentary

Allowing for spontaneous breathing during high-frequency oscillation: the key for final success?

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Abstract

In the present issue of *Critical Care*, van Heerde and colleagues describe a new technical development (a flow-demand system during high-frequency oscillation) that may have an important impact on the future use of high-frequency ventilation in children and adults. Flow compensation on patient demand seems to reduce the imposed work of breathing, may therefore increase patient comfort, and should theoretically allow for maintaining spontaneous breathing while heavy sedation and muscular paralysis could be avoided. With further technical development of this concept, high-frequency oscillation can finally be added to the techniques of mechanical ventilatory support that maintain, rather than suppress, spontaneous breathing efforts. Furthermore, this concept will give high-frequency oscillation the chance to prove its potential role as primary therapy in patients with acute lung injury/acute respiratory distress syndrome, the chance to reduce the incidence of high-frequency oscillation failure for patient or physician discomfort as reported in so many clinical trials in the past, the chance to most probably allow successful weaning from high-frequency oscillation to extubation, and, ultimately, in analogy to what has been reported from the experience with other ventilator modes that allow for maintaining spontaneous breathing, the chance to decrease ventilator days in patients with acute lung injury/acute respiratory distress syndrome.

High-frequency oscillation ventilators were initially designed for neonatal application. With the recognition of the role of ventilator-induced lung injury in the morbidity and mortality of patients with acute lung injury, there has also been increasing interest in the use of high-frequency oscillatory ventilation (HFOV) in adult patients, since it theoretically offers, by design, an ideal mode for lung protection. The need to suppress patients' spontaneous breathing activity with heavy sedation and muscle paralysis because of patient discomfort, due to a significantly increased level of imposed work of breathing (WOB), however, has so far limited the use of HFOV in larger pediatric patients and in adult patients. In the present issue of *Critical Care*, van Heerde and colleagues [1] describe a new

flow-demand system that significantly allows for reducing WOB during HFOV. This new concept, so far tested in a bench test, gives the potential for adult intensive care physicians to more often use HFOV and to further investigate HFOV.

High-frequency oscillatory ventilators can be seen as continuous positive airway pressure (CPAP) devices that allow generation of pressure oscillations around a continuous distending pressure, which will facilitate CO₂ elimination mainly by accelerating the molecular diffusion processes. Accepting HFOV as such a 'super-CPAP' allows one to realize that maintaining spontaneous breathing during HFOV should be nothing other than natural. This maintenance is possible and well tolerated in newborns, and was probably a significant contributor to improved pulmonary outcome in this patient group [2].

As previously shown by van Heerde and colleagues [3], the imposed WOB for a neonate or an infant (up to a bodyweight of 10 kg) on HFOV is considerably low (<0.5 J/l or <1.0 J/l, respectively) during spontaneous tidal breathing with physiologic or smaller tidal volumes between 7 ml/kg to 5 ml/kg – and this is independent of endotracheal tube size. With increasing patient size and weight, the imposed WOB increases fast above 1.0 J/l. Increasing the fresh gas flow rate allows one to reduce the imposed WOB, but not to an acceptable level in the large child or in the adult [3] necessitating heavy sedation, analgesia and often neuromuscular blockade [4]. Using the new flow-demand system, the imposed WOB can be considerably reduced to a maximum of 0.5 J/l during shallow or normal breathing. What could this theoretically mean for HFOV apart from an improvement of patient comfort?

On the basis of currently available data from the experience with airway pressure release ventilation or biphasic positive

CPAP = continuous positive airway pressure; HFOV = high-frequency oscillatory ventilation; WOB = work of breathing.

pressure [5,6] – both methods allowing for unrestricted spontaneous breathing at any phase of the ventilatory cycle because of an integrated high-flow or demand valve CPAP system – it might be postulated that a new high-frequency oscillation ventilator equipped with a flow-demand system allowing for unrestricted spontaneous breathing should allow for less sedation, and should therefore decrease the duration of mechanical support, decrease the length of stay in the intensive care unit, and, ultimately, decrease the overall costs of hospitalization.

The application of HFOV was mainly reported as a rescue ventilatory mode in adult patients with acute respiratory distress syndrome who were thought to have failed conventional ventilation [7]. Outcome results from such studies cannot reflect the real potential of HFOV as a lung protective ventilatory mode. With the possibility of maintaining spontaneous breathing, HFOV could now be used in patients with mild and/or early forms of acute lung injury. With the neonatal experience demonstrating that a lung-protective effect with HFOV requires an early initiation of HFOV before the lung is damaged, continuing until the lung is no longer vulnerable to ventilator-induced injury [2,8], an early transition to HFOV should now be considered in adult acute lung injury/acute respiratory distress syndrome patients, but this will need proper clinical testing. Weaning concepts from HFOV to any form of assisted ventilation or to extubation (as is already possible in newborns and infants [2]) will also need re-evaluation.

In patients with acute respiratory distress syndrome, airway pressure release ventilation with spontaneous breathing has been shown to improve ventilation–perfusion matching, intrapulmonary shunting, and arterial oxygenation [9], indicating recruitment of previously nonventilated lung areas. HFOV at high lung volumes (i.e. recruited lung), which is classically achieved by a stepwise increase in continuous distending pressure to oxygenation and chest X-ray targets, has been shown superior to HFOV at low lung volumes [10]. This high-volume approach during HFOV is often associated with relatively high airway pressures, which can cause hemodynamic compromise necessitating intravascular volume load; the airway pressure might not, however, be sufficient to optimally expand the lungs [11].

In the heavily sedated and paralyzed patient, the continuous distending pressure can be titrated up the inflation limb (to recruit) and down the deflation limb (to find the least pressure required to keep the lungs open) of the static pressure–volume curve, which often allows substantial reduction of mean airway pressures [2,12,13] while reducing hemodynamic side effects to a maximum. With the possibility of benefiting from spontaneous breathing for better recruitment of the dependent lung areas close to the diaphragm, it might become possible to use lower continuous distending pressures to achieve the same oxygenation goals. This may

result, together with the effects of the periodic reduction of intrathoracic pressure resulting from spontaneous breathing, in better venous return to the heart, in improved ventricular filling, and therefore in increased cardiac output and oxygen delivery.

Converting HFOV from a ventilation mode that often requires suppression of spontaneous breathing in larger children and adults to a ‘super-CPAP’ system that allows for unrestricted spontaneous breathing at any phase of the ventilatory cycle because of an integrated high-flow or demand valve system will give HFOV the ultimate chance to prove its real potential for optimal lung protection. The various issues discussed will now need to be addressed.

Competing interests

The author declares that they have no competing interests.

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