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EDITORIAL

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Early detection of deteriorating ventilation: prevention is better than cure!

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Mechanical ventilation represents a life-saving procedure, whose main purpose is to assist the respiratory pump to achieve an adequate pulmonary gas exchange, and should be conducted for the shortest possible period of time. Such assistance may be total, in cases of controlled mechanical ventilation, or partial, when patient and machine interact. Irrespective of the mode used, close monitoring of the effects of mechanical ventilation on oxygenation and CO_2 elimination is essential for guiding adjustments of ventilator settings. If protective mechanical ventilation strategies are applied, monitoring of gas exchange endpoints becomes even more important. The minimization of the mechanical stress to the lung parenchyma brings pH, pO_2, and pCO_2 up to their safety limits, and sudden deterioration of ventilation may cause harm.

The monitoring of ventilation at the bedside is usually provided by flow and pressure sensors internal to the mechanical ventilator. In pediatrics, tidal volumes are small relative to the volume of the respiratory circuit. Therefore, "loss" of ventilation due to air volume compression, as well as compliance of the ventilator circuit, may become a concern. Such a reduction in ventilation may result in hypoxia and hypercapnia, leading to hemodynamic instability and even intracranial hemorrhage [1, 2]. On the other hand, inaccurate measurement of delivered ventilation, as for example during pressure-controlled ventilation, may yield high tidal volumes and increased transpulmonary pressures, resulting in lung edema [3], damage of the lung parenchyma [3], and production of inflammatory cytokines [4]. In genetically susceptible extremely low gestational age newborns, such injury may contribute to the development of bronchopulmonary dysplasia [5], with major impact on morbidity and mortality. Thus, it was recommended that in infants exhaled tidal volumes should be assessed with pneumotachographs placed closer to the endotracheal tube to monitor the truly delivered ventilation [6]. Unfortunately, however, even an accurately measured exhaled tidal volume is no guarantee that ventilation is adequate, especially when sudden changes in regional ventilation occur, for example following atelectasis, pneumothorax, and endotracheal tube displacement.

In this issue of *Intensive Care Medicine*, Waisman and colleagues [7] report on the performance of a system for the detection of impaired ventilation that is based on the analysis of the chest wall motion. Building on a previous publication by the same group [8], these authors placed miniature accelerometers (motion sensors) on each chest side and epigastrium of mechanically ventilated rabbits, while applying common clinical respiratory monitoring, including peripheral oxygen saturation, end-tidal partial CO_2 pressure, airway pressure and flow, as well as hemodynamic monitoring, namely heart rate and blood pressure. Animals were then submitted to different ventilation challenges: (1) different levels of reduction in peak inspiratory pressure; (2) bronchial intubation with one-lung ventilation; and (3) slowly progressing pneumothorax. As expected, the motion sensors detected changes in global chest wall mechanics, or in its symmetry, within 1–2 breaths, whereas traditional monitoring variables needed seconds to minutes to detect the deterioration in ventilation. Following slowly progressive pneumothorax, mean arterial pressure and peripheral oxygen saturation decreased after approximately 20 and 69 min, respectively, whereas asymmetric ventilation was detected as early as 13 min after the challenge.

The impact of impaired ventilation on oxygenation can be compensated to a large extent by different mechanisms, especially the hypoxic pulmonary vasoconstriction, which will deviate perfusion from hypoxic lung zones towards better oxygenated ones [9]. If such a mechanism is intact, hypoxemia may develop slowly and be limited. Furthermore, the hemoglobin dissociation curve for oxygen is relatively flat at higher partial pressures, making the monitoring of peripheral oxygen saturation less sensitive to changes in oxygenation. Also, changes in alveolar ventilation may need several breaths to be detectable as a drop in end-tidal CO_2, depending on the relationship between tidal volume and functional residual capacity [10], especially if the phase III of the capnogram is flat. In addition, a slowly developing change in cardiac preload and cardiac output, which usually accompany the formation of mild pneumothorax, may be partially compensated by increased tonus of the peripheral arterioles, remaining possibly unnoticed by conventional clinical hemodynamic monitoring during a certain period of time [11]. Thus, the technique proposed by Waisman and colleagues [7] is also potentially interesting for detecting deteriorating ventilation owing to its simplicity. However, it also has important limitations. First, the use of motion sensors, as currently presented in this publication, may pose difficulties to nursery care, and acceptance by caregivers may become an issue. Second, movement artifacts and change in body position may be confounded with deteriorating ventilation if not adequately filtered. Third, such sensors are less valuable for understanding a static condition than for tracking trends. Thus, correct interpretation of values, and even of trends, will likely require the use of other devices. Fourth, it is conceivable that motion sensors may become less sensitive to deteriorating ventilation if the chest wall becomes stiffer. In the pediatric population, the compliance of the chest wall decreases importantly after the second year of life [12], possibly influencing the signal-to-noise ratio and the performance of motion sensors.

The maxim that it is better to avoid bad things happening than to fix bad things once they have happened applies to several aspects of life. This might be particularly true in pediatric intensive care medicine, since compensatory mechanisms are less well developed and once injury happens, the consequences are usually worse and may last longer than in older ages. Provided the technique described in this issue of *Intensive Care Medicine* proves useful for daily practice, intensive care pediatricians may acquire a new tool to for monitoring of ventilation. Our grandmas were essentially right when they used to say, “prevention is better than cure”.

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