

The use of mechanical power to study weaning and extubation success

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Recent research has studied the concept of ventilator mechanical power (MP) as an index of lung mechanics.^{1,2} This index is a summary parameter derived from the respiratory rate, tidal volume, and the pressure needed to deliver the tidal volume.^{3,4} It quantifies the energy transferred from the ventilator to the patient's respiratory system during the respiratory cycle to overcome the elastic and resistive forces of the lungs and chest wall to provide adequate gas exchange. Higher levels of MP reflect more abnormal lung mechanics, and serial measurements of MP can help characterize changes in the mechanical properties of the lung and the disease course during mechanical ventilation. These changes should reflect the clinical course of the underlying respiratory disorder and potentially identify patients developing ventilator-induced lung injury.

Several investigators have measured MP prior to extubation to determine whether or not this parameter could help predict successful weaning and extubation. This letter to the editor reviews two recent articles to provide clinicians with information about the potential use of mechanical power in making decisions regarding weaning and extubation. Ghiani et al., prospectively studied 130 patients with tracheostomies referred to a specialized hospital for weaning.⁵ These patients underwent a structured weaning program, and ventilator parameters were collected 48 hours after the first spontaneous breathing trial and 48 hours before the completion of the weaning program. Variables included dynamic lung-thorax compliance, mechanical power, mechanical power adjusted for ideal body weight, and mechanical power adjusted for dynamic thoracic compliance. The threshold value for predicting weaning failure was 20.3 Joules/minute. Mechanical power

adjusted for dynamic lung-thorax compliance predicted weaning success with a positive likelihood ratio of 3.3 and a negative likelihood ratio of 0.3. The mechanical power calculation in this study used the following equation: $MP \text{ (Joules/min)} = 0.098 \times V_t \times RR \times P_{max}$ on a pressure controlled mode.

Yan et al., analyzed the association between MP and weaning outcomes in critically ill patients on mechanical ventilation.^{6,7} They downloaded information from the Medical Information Mart for Intensive Care IV that contains information on 76,540 ICU admissions at Beth Israel Deaconess Medical Center in Boston between 2008 and 2019. The criteria for a weaning trial included a T-tube test, which lasted between 30 and 120 minutes on the same FiO_2 the patient was on during ventilation prior to the test. They collected information on ventilator parameters, MP, dynamic lung compliance, dynamic driving pressure, MP corrected for dynamic lung-thorax compliance, and MP corrected for predicted body weight. The study cohort eventually included 3695 patients who underwent a spontaneous breathing trial that was recorded in the data set. The weaning failure rate included the termination of the spontaneous breathing trial and reintubation or noninvasive respiratory support or death within the first 48 hours postextubation and was 38.5% (1421 out of 3695). The reintubation rate, or the requirement for noninvasive mechanical ventilation, or death within 48 hours of the first successful spontaneous breathing trial and extubation was 11.1% (283 out of 2557). Patients with weaning failure had higher plateau pressures, peak pressures, respiratory rates, minute ventilations, MP, dynamic compliance, MP adjusted for dynamic compliance, and MP adjusted for predicted body weight. The MP levels were 9.2 Joules/minute (6.0–13.2) in the successful weaning patients and 14.6 Joules/minute (10.6–20.2) in the weaning failure patients. When patients were classified according to success, 1 failure, 2 failures, or 3 failures, the MP progressively increased in each failure group. When MP was calculated at 4-hour intervals for 24 hours prior

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to the SBT trial, it decreased in patients who had a successful trial and did not change in patients who had an unsuccessful trial. The mechanical power calculation in this study used the following equation: $MP \text{ (joules/min)} = 0.098 \times V_t \times RR \times [P_{\text{peak}} - 0.5 \times (P_{\text{plat}} - P_{\text{EEP}})]$. This study used a very large database, and it may reasonably reflect outcomes in “average” ICU patients on ventilators.

The research conducted by Ghiani and Yan demonstrates important associations between MP adjusted for lung-thorax compliance and weaning success and indicate that higher adjusted MP levels are associated with an increased likelihood of weaning failure.^{5,7} However, there are important differences between these two studies, including the calculation of mechanical power that depends on the ventilator mode and the weaning protocol. The mechanical power measurements in these two studies were not used to make decisions about weaning and extubation, but they could help identify patients with more abnormal lung mechanics who might not manage the increased work of breathing after extubation. These results also suggest that MP should be monitored during mechanical ventilation as an index of lung stress; the lack of improvement may indicate persistent lung injury and possibly ongoing ventilator-induced lung injury. Conversely, decreases in MP reflect improvement in lung mechanics and presumably recovery from the acute disorder causing respiratory failure. The adjustment of MP for lung-thorax compliance provides a composite index of ventilator work and thoracic compliance, which includes the effect of the chest wall and abdomen on the work of breathing.

Clinicians should consider the mechanical power as an important index of the severity of the lung injury and of changes in mechanical properties of the respiratory system during mechanical ventilation. The calculation of mechanical power does not replace current protocols for the adjustment of mechanical ventilation support or for weaning and extubation. Hopefully, future ventilators will incorporate the software needed to make these calculations routinely available, and this should provide additional information about the status of the lung parenchyma and potentially improve clinical decision making.

Keywords: mechanical ventilation, mechanical power, lung injury, extubation

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