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The mechanical power of prone ventilation

Ryan Thomas Lee, [1] John Christian Widere [2]

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Abstract

Prone ventilation has been shown to reduce mortality in moderate to severe acute respiratory distress syndrome (ARDS) by enhancing oxygenation, improving lung mechanics, and reducing ventilator-induced lung injury. While the arterial oxygen partial pressure (PaO_2 mmHg) to fraction of inspired oxygen (FiO_2) ratio (P:F) has traditionally been utilized to grade ARDS severity, multiple supplementary markers of oxygenation and ventilation, such as the oxygenation index (OI) and ventilatory ratio (VR), offer additional insight on pulmonary function in addition to prognostic information for outcomes in ARDS.

Mechanical power (MP), a comprehensive marker used to quantify the total energy transferred from the ventilator to the lungs by combining tidal volume, distending pressure, flow and respiratory rate, has recently gained attention as a potential future target of lung protective ventilation. Here we present an illustrative case of how prone positioning may lead to improved objective and physiologic markers of lung mechanics related to these variables and review the available literature.

Keywords: Mechanical power, Prone ventilation, ARDS

Authors:

1. MD, Division of Anesthesia Critical Care, Departments of Anesthesiology and Emergency Medicine, University of Virginia, Charlottesville, Virginia, USA
2. MD, Division of Pulmonary and Critical Care Medicine, Department of Medicine, Charlottesville, Virginia, USA

Corresponding author: znn7yf@uvahealth.org
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Case

A 75-year-old female with a medical history of chronic kidney disease, type II diabetes, hypertension, hyperlipidemia, and coronary artery disease on dual antiplatelet therapy presented to the emergency department (ED) in respiratory distress, quickly progressing to cardiac arrest. She was intubated in the ED and return of spontaneous circulation (ROSC) was obtained after 25 minutes. Initial CT-imaging revealed diffuse ground-glass opacities and dense dependent lung consolidations most likely representing pulmonary contusion and hemorrhage from CPR as well as aspiration of gastric contents (Figure 1).

On admission to the intensive care unit (ICU), despite neuromuscular blockade and ventilator optimization, on volume control (VC) set to a tidal volume of 360 ml (8ml/kg predicted body weight (PBW), respiratory rate of 34, positive end expiratory pressure (PEEP) of 16 cmH_2O with resultant peak (PIP) and plateau (Pplat) pressures of 44 cmH_2O and 31 cmH_2O, respectively, and FiO_2 of 100%, she continued to have severe mixed respiratory failure with arterial blood gas (ABG) showing pH 7.18 / $PaCO_2$ 58 mmHg / HCO3 21 mmol/L / PaO_2 69 mmHg. This resulted in a P:F of 69, oxygenation index (OI) of 43, ventilatory ratio (VR) of 4.73, and mechanical power (MP) of 43.8 J/min.

She underwent prone positioning and following two sessions her ABG showed marked improvement to pH 7.40 / $PaCO_2$ 35 mmHg / HCO_3 22 mmol/L / PaO_2 107 mmHg on VC with tidal volumes of 280 ml (6.2ml/kg PBW), respiratory rate of 30, PEEP of 12 cmH_2O, PIP and Pplat of 34 cmH_2O and 21 cmH_2O, respectively, and FiO_2 of 35%. Objective markers of pulmonary function have also improved, with a P:F of 305, OI of 2, VR of 1.96, and MP of 24.3 J/min. The patient required no further sessions of prone ventilation and was weaned to pressure support trials 48 hours later.

Figure 1: CT imaging showing dorsal predominant consolidation consistent with suspected aspiration with diffuse ground glass opacities concerning for pulmonary hemorrhage in the setting of prolonged CPR and dual antiplatelet therapy.

Discussion

Since the landmark PROSEVA trial in 2013 demonstrated a 16% absolute reduction in 28-day mortality with 16 hours of daily treatment, prone ventilation has become a hallmark of managing patients with moderate to severe ARDS. [1] The survival benefit from prone positioning is thought to derive from mechanisms beyond improved gas exchange alone, including improved lung mechanics via more homogenous distribution of mechanical ventilatory stress and strain,

thereby reducing ventilator induced lung injury (VILI) and potentially reducing extrapulmonary organ injury by reducing systemic inflammation. [2] Additional proposed beneficial mechanisms of prone positioning include improved ventilation-perfusion matching (V/Q), reduced transpulmonary gradients and improved right heart function as a result of decreased pulmonary vascular resistance, and a reduction in the compressive force of the heart and mediastinal structures on the dorsal lung regions. [3] The case presented here illustrates how prone positioning can lead to both improved oxygenation, ventilation, and mechanical ventilator-pulmonary dynamics via improved P:F, OI, VR, and MP, each of which provide unique insights to the physiologic alterations induced by prone ventilation and have important effects on our approach to lung protective mechanical ventilation.

The P:F ratio is the marker by which ARDS is graded, being mild, moderate, and severe for <300, <200, and <100, respectively. It is also utilized to predict which patients may benefit from more aggressive treatment approaches, such as neuromuscular blockade, high PEEP strategies, and prone positioning. In the PROSEVA trial, prone positioning for patients with moderate to severe ARDS (P:F <150) led to a significant improvement in the P:F ratio by days 3 and 5, however the difference became non-significant by day 7. Multiple subsequent trials have demonstrated an association between improvements in the P:F before and after prone ventilation with reduced mortality. [4,5,6] This improvement is likely due to increases in lung volume, alveolar recruitment of previously non-aerated lung, and better V/Q matching in the prone position also allowing for more lung protective ventilation.3 This may be especially pronounced in patients with dorsal consolidations, as in our patient, by reducing lung compression by mediastinal structures and enhancing recruitment of dorsal alveoli in the prone position.

While the P:F ratio has been heavily relied upon when grading ARDS severity, it considers only FiO_2 and fails to take into account PEEP and mean airway pressure, each of which contribute greatly to oxygenation by a combination of alveolar recruitment, promoting homogenous lung aeration, and reducing shunt. The oxygenation index (OI), defined as (FiO_2 x mean airway pressure x 100)/ PaO_2, supplements the P:F by informing clinicians about intensity of mechanical ventilation required for adequate oxygenation. OI values <25 have been correlated with good outcomes, while scores >40 suggest a need for advanced therapies including extracorporeal membrane oxygenation (ECMO). [7]

Studies have demonstrated that the OI typically decreases shortly after prone position ventilation and may be a better predictor of mortality than the P:F ratio. [8,9] From a practical perspective, it can be helpful to keep in mind that for the same P:F ratio, a patient on a higher PEEP or mean airway pressure may have more severe pulmonary disease than a patient on a lower PEEP or mean airway pressure, and as such using P:F ratio without any consideration for the intensity of ventilatory support can be deceiving.

While the OI takes into account airway pressure, neither the P:F or OI account for reduced ventilation, also commonly affected in ARDS. Pulmonary dead space fraction has been shown to be an independent predictor of mortality in ARDS, just like the P:F, yet seldom used in practice due to the additional ventilator components required to accurately measure. [10] The ventilatory ratio (VR) is a simple bedside index calculated using routinely measured respiratory variables and is a measure of impaired ventilation, defined as (minute ventilation × $PaCO_2$)/(predicted body weight × 100 × 37.5), and has been shown to be independently associated with increased risk of mortality after adjusting for P:F, PEEP, and APACHE II score, with a value >2 predicting significantly lower ARDS survival. [11,12] Decreases in the VR with prone positioning have also been shown to predict survival in adult patients with ARDS receiving prone positioning. [13,14]

Traditionally, ventilation parameters associated with VILI such as tidal volume, plateau and driving pressures have been studied in isolation. Mechanical power (MP) integrates tidal volume, distending pressure, flow, and respiratory rate into a unified measure of energy, i.e. potential injury, applied by the ventilator to the lung each minute. [15] MP has been consistently associated with increased mortality in ARDS, even when lung-protective ventilation strategies are employed. [16,17] In a retrospective analysis including 8207 patients, a consistent increase in the risk of death was shown with mechanical power greater than 17 J/min. [18] As might be expected by the changes in ventilator-pulmonary mechanics with prone positioning, applied mechanical power has been shown to decrease with prone positioning and to correlate with ICU mortality. [19,20] To date, there is a lack of prospective randomized data evaluating MP, and it remains to be determined if MP represents a maker of disease severity, a safety limit, or goal for mechanical ventilation.

Conclusion

Early prone positioning has been one of the most significant interventions for reducing mortality in ARDS over the last two decades. It has powerful effects on oxygenation, ventilation, and lung recruitment, leading to more homogenous distribution of ventilator energy and ultimately

allowing for more lung protective ventilation and decreased mortality. Each of the objective markers discussed here, namely the P to F ratio, oxygenation index, ventilatory ratio, and mechanical power can be useful in predicting ventilator weaning success with prone positioning and provide insight to the various mechanisms by which prone positioning may reduce VILI, facilitate liberation from mechanical ventilation, and reduce mortality.

References

1. Guérin C, Reignier J, Richard JC, et al. Prone positioning in severe acute respiratory distress syndrome. N Engl J Med 2013; 368(23):2159-2168.

2.Hadaya J, Benharash P. Prone positioning for acute respiratory distress syndrome (ARDS). JAMA 2020; 324(13):1361.

3. Guerin C, Baboi L, Richard JC. Mechanisms of the effects of prone positioning in acute respiratory distress syndrome. Intensive Care Med 2014; 40(11):1634-1642.

4. Lee HY, Cho J, Kwak N, et al. Improved oxygenation after prone positioning may be a predictor of survival in patients with acute respiratory distress syndrome. Crit Care Med 2020;48(12):1729-1736.

5. Liang H, Deng Q, Ye W, et al. Prone position ventilation-induced oxygenation improvement as a valuable predictor of survival in patients with acute respiratory distress syndrome: a retrospective observational study. BMC Pulm Med 2024; 24(1):575.

6. Sud S, Friedrich JO, Taccone P, et al. Prone ventilation reduces mortality in patients with acute respiratory failure and severe hypoxemia: systematic review and meta-analysis. Intensive Care Med 2010; 36(4):585-599.

7. Muniraman HK, Song AY, Ramanathan R, et al. Evaluation of oxygen saturation index compared with oxygenation index in neonates with hypoxemic respiratory failure. JAMA Netw Open 2019; 2(3):e191179.

8. Harbut P, Campoccia Jalde F, Dahlberg M, et al. Improved oxygenation in prone positioning of mechanically ventilated patients with COVID-19 acute respiratory distress syndrome is associated with decreased pulmonary shunt fraction: a prospective multicenter study. Eur J Med Res 2023; 28(1):597.

9. Davies K, Bourdeaux C, Peiris T, et al. Oxygenation index outperforms the P/F ratio for mortality prediction. Crit Care 2014; 18(Suppl 1):266.

10. Nuckton TJ, Alonso JA, Kallet RH, et al. Pulmonary dead-space fraction as a risk factor for death in the acute respiratory distress syndrome. N Engl J Med 2002; 346(17):1281-1286.

11. Sinha P, Calfee CS, Beitler JR, et al. Physiologic analysis and clinical performance of the ventilatory ratio in acute respiratory distress syndrome. Am J Respir Crit Care Med 2019; 199(3):333-341.

12. Monteiro ACC, Vangala S, Wick KD, et al. The prognostic value of early measures of the ventilatory ratio in the ARDS ROSE trial. Crit Care 2022; 26(1):297.

13. Tisminetzky M, Ferreyro BL, Frutos-Vivar F, et al. Decline in ventilatory ratio as a predictor of mortality in adults with ARDS receiving prone positioning. Respir Care 2022; 67(9):1067-1074.

14. Wang Z, Xia F, Dai H, et al. Early decrease of ventilatory ratio after prone position ventilation may predict successful weaning in patients with acute respiratory distress syndrome: A retrospective cohort study. Front Med (Lausanne) 2022; 9:1057260.

15. von Düring S, Parhar KKS, Adhikari NKJ, et al. Understanding ventilator-induced lung injury: The role of mechanical power. J Crit Care 2025; 85:154902.

16. van Meenen DMP, Algera AG, Schuijt MTU, et al. Effect of mechanical power on mortality in invasively ventilated ICU patients without the acute respiratory distress syndrome: An analysis of three randomized clinical trials. Eur J Anaesthesiol 2023; 40(1):21-28.

17. von Düring S, Liu K, Munshi L, et al. The association between mechanical power within the first 24 hours and icu mortality in mechanically ventilated adult patients with acute hypoxemic respiratory failure: A registry-based cohort study. Chest 2025; 168(4):901-911.

18. Serpa Neto A, Deliberato RO, Johnson AEW, et al. Mechanical power of ventilation is associated with mortality in critically ill patients: an analysis of patients in two observational cohorts. Intensive Care Med 2018; 44(11):1914-1922.

19. Boesing C, Krebs J, Conrad AM, et al. Effects of prone positioning on lung mechanical power components in patients with acute respiratory distress syndrome: a physiologic study. Crit Care 2024; 28(1):82.

20. Wu Y, Liufu R, Wang YY, et al. Association between mechanical power during prone positioning and mortality in patients with acute respiratory distress syndrome. Crit Care Med 2025; 53(11):e2144-e2155.