Concept of Mechanical Power and Mechanical Energy in pediatric ventilated patients. What do we know ?

Background: When expressed in terms of Power in Joules/min (J/min), the energy transferred to the lungs is known as Mechanical Power (MP)(1,2,3).

MP = RR x ΔV2 x ½ x ELrs + RR x (1+I:E) x Raw. + ΔV x PEEP

MP can be altered by the changes in Tidal Volume (Vt), Gas Flow (F), Airway Resistance (Raw), Peak End Expiratory Pressure (PEEP), I:E Ratio, and Respiratory Rate (RR).(2)

Accumulating evidence is now showing MP to be an important causative factor for significant Ventilator Induced Lung Injury (VILI).(1,2,4)

ACADEMIC P.E.A.R.L.S

Pediatric Evidence And Research Learning Snippet

Concept of Mechanical Power and Mechanical Energy in pediatric ventilated patients. What do we know ?

- Most children are ventilated on Pressure Control (PC) Mode and Gattinoni's equation of MP is designed for Volume control mode.
- Chiumello et al.(5) have suggested a surrogate formula to calculate MP in patients on PC mode, which is : MP = 0.098 x RR x VT x (ΔP + PEEP)(5)
- In children, the weight increases and RR decreases as the age increases, and this would affect the calculated MP as Vt per Kg and RR would change.
- Martin Kneyber(6) and colleagues tried to solve these hurdles by removing RR from the equation of MP and suggested using mechanical energy (Mers) instead of MP.
- The mechanical energy of the respiratory system (MErs) was calculated by the formula 0.098 × (Vt × kg− 1) × (PIP − [(Pplat − PEEP)/2]).
- Here, Pplat was calculated by a 3-second of inspiratory pause on PC mode in well sedated and paralyzed children.
- The authors analysed the data of 312 patients with a median age of 7.8 (1.7–44.2) months. Age ($p < 0.001$), RR ($p < 0.001$), and Vt ($p< 0.001$) were independently associated with MP.
- MErs but not MP correlated significantly ($p < 0.001$) better with lung pathology. About 33% of all energy generated by the ventilator was transferred to the lung and highly dependent on lung compliance and airway resistance but not on endotracheal tube size (ETT) during PC mode ventilation.

Conclusion: MErs seemed to be better related to underlying lung pathology and patient outcome than MP in pediatric ventilated patients.

EXPERT COMMENT

"Removing RR from the equation of MP, as suggested by Martin Kneyber et al. 6, can not solve the problem of confounding factor of RR in the pediatric age group, as RR remains a significant factor in the equation of MP. Therefore, we need to look for some better solutions to solve this problem. Apart from MP, there are non-ventilatory factors like multiorgan dysfunctions, fluid over load, hypo or hyper inflammatory type of ARDS etc which can also be important factors for morbidity and mortality in pARDS (7,8,9)

Driving Pressure is one independent variable, which, although a part of the equation of MP, has its impact on outcomes in ventilated patients(4).

We need to find the safe cut-off limits of MP and DP in pediatric ventilated patients and explore whether we can use MP as a prognostic marker of Ventilation-induced lung injury (VILI) or as one causative factor VILI."

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With warm regards,

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Reference

Marini JJ. Evolving concepts for safer ventilation. *Crit Care.* 2019 Jun 14;23(Suppl 1):114. 2- Cressoni M, Gotti M, Chiurazzi C et al: Mechanical Power and Development of Ventilator-induced Lung Injury. *Anesthesiology.* 2016 May;124(5):1100-8. 3- Gattinoni L, Tonetti T, Cressoni M et al: Ventilator-related causes of lung injury: the mechanical power. *Intensive Care Med.* 2016 Oct;42(10):1567-1575 4-Guérin C, Papazian L, Reignier J et al: investigators of the Acurasys and Proseva trials. Effect of driving pressure on mortality in ARDS patients during lung protective mechanical ventilation in two randomized controlled trials. *Crit Care.* 2016 Nov 29;20(1):384. 5- Chiumello D, Gotti M, Guanziroli M et al: Bedside calculation of mechanical power during volume- and pressure-controlled mechanical ventilation. *Crit Care.* 2020 Jul 11;24(1):417. 6- Kneyber, M.C.J., Ilia, S., Koopman, A.A. *et al.* Energy transmission in mechanically ventilated children: a translational study. *Crit Care* **24,** 601 (2020). https://doi.org/10.1186/s13054-020-03313-7 7- Khemani RG, Smith L, Lopez-Fernandez YM et al: Paediatric acute respiratory distress syndrome incidence and epidemiology (PARDIE): an international, observational study. *Lancet Respir Med.* 2019 Feb;7(2):115-128. 8- Marini JJ. Evolving concepts for safer ventilation. *Crit Care.* 2019 Jun 14;23(Suppl 1):114. 9- Calfee CS, Delucchi KL, Sinha P et al: Irish Critical Care Trials Group. Acute respiratory distress syndrome subphenotypes and differential response to simvastatin: secondary analysis of a randomised controlled trial. *Lancet Respir Med.* 2018 Sep;6(9):691-698.