illness are not associated with energy and protein delivery. Nutr Burbank Los Angel Cty Calif. 2021;82:111061.
8. Fetterplace K, Beach LJ, MacIsaac C, Presneill J, Edbrooke L, Parry SM, et al. Associations between nutritional energy delivery, bioimpedance spectroscopy and functional outcomes in survivors of critical illness. J Hum Nutr Diet Off J Br Diet Assoc. 2019;32:702–12.
9. Breen L, Phillips SM. Skeletal muscle protein metabolism in the elderly: interventions to counteract the «anabolic resistance» of ageing. Nutr Metab. 2011;8:68.
10. Gutiérrez Zárate D, Rosas Sánchez K, Cerón Díaz U, Limbert Sagardia C, Martínez Zubieta R, Gutiérrez Zárate D, et al. Ultrasonografía del musculoesquelético como valoración nutricional en el paciente crítico. Med Crítica Col Mex Med Crítica. 2017;31:122–7.

Alan Garcia-Grimaldo[a,b,1],
Nadia Carolina Rodríguez-Moguel[c,1],
Martín Armando Ríos-Ayala[a],
Carmen Margarita Hernández-Cárdenas[d],
Lya Pensado-Piedra[e], Iván Armando Osuna-Padilla[a,*,1]

[a] *Coordinación de Nutrición Clínica, Departamento de Áreas Críticas. Instituto Nacional de Enfermedades Respiratorias Ismael Cosio Villegas, Mexico City, Mexico*
[b] *Sección de Estudios de Posgrado e Investigación, Escuela Superior de Medicina, Instituto Politécnico Nacional, Mexico City, Mexico*
[c] *Departamento de Investigación en Enfermedades Infecciosas, Instituto Nacional de Enfermedades Respiratorias Ismael Cosio Villegas, Mexico City, Mexico*
[d] *Dirección General, Instituto Nacional de Enfermedades Respiratorias Ismael Cosío Villegas, Mexico City, Mexico*
[e] *Departamento de Imagenología, Instituto Nacional de Enfermedades Respiratorias Ismael Cosío Villegas, Mexico City, Mexico*

* Corresponding author.
E-mail address: ivan.osuna@cieni.org.mx
(I.A. Osuna-Padilla).
[1] These authors contribute equally to this work.

https://doi.org/10.1016/j.medin.2023.12.010

https://doi.org/10.1016/j.medin.2024.03.018

High rate-trauma: the new world order?

Trauma relacionado a alta frecuencia: ¿El nuevo orden mundial?

When the lung parenchyma is exposed to cyclic stress, lung compliance inevitably begins to decrease.[1] Respiratory rates higher than 25 per minute, generate a higher energy transfer,[2] which leads to a higher heterogeneous strain mainly due to a lower lung resilience capacity.[3] High respiratory rates produce hypocapnia and respiratory alkalosis, but also cause direct injury through chemical effects as a consequence of the alteration of mechanoreception reflexes, which is ultimately associated with greater morbidity and mortality.[4]

If the oscillatory frequency of the lung tissue exceeds the maximum limit of its elastic behavior, the heterogeneous variability of the strain[5] and the affectation in the capacity of the parenchyma to assimilate the transmitted energy (stress), will result in a decrease of the tissue resistance with a tendency to zero, which will lead to the appearance of micro ruptures of the pulmonary cytoskeleton.[6]

The recent study published by the Mechanical Power Day [MPD] group,[7] by applying the formula proposed by Gattinoni et al.,[8] showed a mean mechanical power (MP) of 19.20 J/min (SD 8.44) for patients on pressure-controlled ventilation (PC-CMVs) and 16.01 J/min (SD 6.88) for those on volume-controlled ventilation (VC-CMVs). However, the researchers propose an interesting formula for the calculation of MP, using strain and strain-rate subrogates, based on solid concepts of materials engineering and thermodynamics, which have already been used in other clinical studies.[9] A relevant point is the time factor, which is also implicit in the subrogation of the strain-rate according to the formula proposed by the MPD group. In VC-CMVs, the strain-rate corresponds to Flow ratio/PEEP and DP to strain; whereas in PC-CMVs, the strain-rate corresponds to subrogated strain (ETv/PEEP)/inspiratory time.

The authors reported a mean of 17 breaths per minute in both groups (PC-CMVs and VC-CMVs), with no significant difference (Welch, $p = 0.12$).

We performed an analysis post hoc of the MPD using frequentist statistics to evaluate the behavior of the respiratory rate, analyzing the variables that are part of the MP equation proposed by González-Castro et al.,[7] of the multicenter and international cross-sectional cohort.[7] We decided to dichotomize the sample between those with high-energy MP (>17 J/min) and compare them with those with low-energy MP (<17 J/min), as supported by current evidence.[8]

Bivariate analysis showed that respiratory rate behaved as a risk factor for high-energy MP, regardless of the ventilatory mode used (PC-CMVs; OR 1.56, 95% CI: 1.32–1.84; $p < 0.01$/VC-CMVs; OR 1.46; 95% CI: 1.29–1.65; $p < 0.02$). In the multivariate analysis [Table 1], although PEEP was the variable that showed the greatest association with risk of high-energy MP, the behavior of respiratory rate was very similar in both ventilatory modes, showing a greater probability of association with high-energy MP both in those patients ventilated in PC-CMVs (OR 1.96; 95% CI: 1.50–2.55; $p < 0.01$), as well as in those on VC-CMVs (OR 1.41; 95% CI: 1.23–1.62; $p < 0.01$) [Table 1 and Fig. 1].

In PC-CMVs, for a respiratory rate >20 bpm, an ROC of 81% was obtained, corresponding to a specificity of 91.43% [LR(+) 5.02]. Likewise, in VC-CMVs, for the same respiratory

Table 1 Multivariate analysis of the MP according to the model proposed by the MPD group.

Variable	PC-CMVs			VC-CMVs		
	OR	95% CI	*p*	OR	95% CI	*p*
Strain subrogate	1.09	0.97–1.2	0.15	1.20	1.06–1.35	<0,01
PEEP	4.58	1.24–16.94	<0.05	1.89	1.40–2.56	<0.01
Strain-rate subrogate	1.02	0.97–1.06	0.44	1.29	1.05–1.58	<0.05
Respiratory rate	2.08	1.52–2.84	<0.01	1.41	1.23–1.62	<0.01
Expiratory tidal volume	1.01	0.99–1.03	0.39	–	–	–
Inspiratory time	1.96	0.03–148.95	0.76			

OR: odds ratio, CI: confidence interval.
For the PC-CMVs model, the total variance inflation factor (VIF) was 5.25, with strain subrogate being the variable with the highest value of concern, computed at the maximum limit of tolerance. For the VC-CMVs model, the VIF was 1.33, and there was no value of concern.

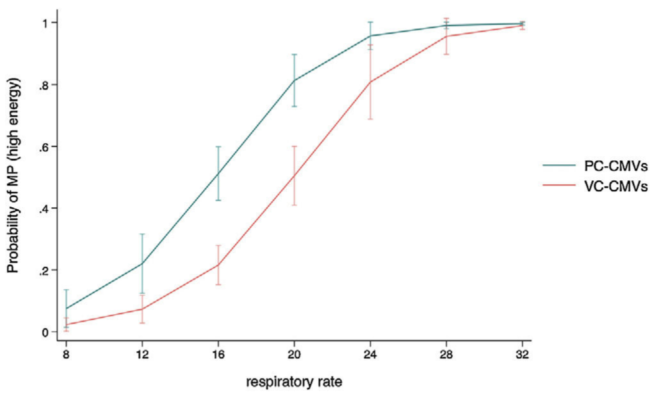

Figure 1 Predictive margins with 95% Cis of MP (high energy, >17 J/min), according to respiratory rate, and for each ventilatory mode.

rate range, an ROC of 82% and a specificity of 83.62% [LR(+) 3.63] was obtained.

The result of our analysis is similar to that reported by Azizi et al.,[10] who report that high respiratory rates (>26 bpm) correlate with higher MP (pseudo R^2: 0.021; $p < 0.01$) and consequently with higher mortality.

In conclusion, after performing a post hoc analysis of the MPD and using frequentist statistics, we observed that high respiratory rates were associated with a greater probability of generating high-energy MP, regardless of the ventilatory mode. This attractive hypothesis derived from the findings of our study highlights a gap in the current knowledge that will need to be addressed by further and more comprehensive research.

Authors' contribution

AF-C performed the study design, formal statistical analysis, wrote and edited the present manuscript; MI-E, AG-C, AC, JN-S performed the formal revision and edited this manuscript. All authors read and approved the final manuscript.

Funding

This work did not receive any funding.

Conflict of interest

All authors declare no conflict of interest.

References

1. Arora H, Mitchell RL, Johnston R, Manolesos M, Howells D, Sherwood JM, et al. Correlating local volumetric tissue strains with global lung mechanics measurements. Materials (Basel). 2021;14(2). Available from: https://www.mdpi.com/1996-1944/14/2/439
2. Tonna JE, Peltan ID, Brown SM, Grissom CK, Presson AP, Herrick JS, et al. Positive end-expiratory pressure and respiratory rate modify the association of mechanical power and driving pressure with mortality among patients with acute respiratory distress syndrome. Crit Care Explor. 2021;3(12). Available from: https://journals.lww.com/ccejournal/fulltext/2021/12000/positive_end_expiratory_pressure_and_respiratory.10.aspx
3. Modesto i Alapont V, Aguar Carrascosa M, Medina Villanueva A. Stress, strain and mechanical power: is material science the answer to prevent ventilator induced lung injury? Med Intensiva (Engl Ed). 2019;43(3):165–75. Available from:
4. Laffey JG, Kavanagh BP. Hypocapnia. N Engl J Med. 2002;347(July (1)):43–53.
5. Hu X, Zhang Y, Cheng D, Ding Y, Yang D, Jiang F, et al. Mechanical stress upregulates intercellular adhesion molecule-1 in pulmonary epithelial cells. Respiration. 2008;76(3):344–50. Available from: https://doi.org/10.1159/000137509
6. Eskandari M, Arvayo AL, Levenston ME. Mechanical properties of the airway tree: heterogeneous and anisotropic pseudoelastic and viscoelastic tissue responses. J Appl Physiol. 2018;125(September (3)):878–88.
7. González-Castro A, Medina-Villanueva A, Escudero-Acha P, Fajardo-Campoverdi A, Gordo-Vidal F, Martin-Loeches I, et al. Comprehensive study of mechanical power in controlled mechanical ventilation: prevalence of elevated mechanical power and component analysis. Med Intensiva (Engl Ed). 2023:1–10.
8. Gattinoni L, Tonetti T, Cressoni M, Cadringher P, Herrmann P, Moerer O, et al. Ventilator-related causes of lung injury: the mechanical power. Intensive Care Med. 2016;42(October (10)):1567–75.
9. Chiumello D, Gotti M, Guanziroli M, Formenti P, Umbrello M, Pasticci I, et al. Bedside calculation of mechanical power during volume- and pressure-controlled mechanical ventilation. Crit Care. 2020;24(1):417. Available from: https://doi.org/10.1186/s13054-020-03116-w

10. Azizi BA, Munoz-Acuna R, Suleiman A, Ahrens E, Redaelli S, Tartler TM, et al. Mechanical power and 30-day mortality in mechanically ventilated, critically ill patients with and without coronavirus disease-2019: a hospital registry study. J Intensive Care. 2023;11(1):14. Available from: https://doi.org/10.1186/s40560-023-00662-7

Aurio Fajardo-Campoverdi[a,*,1], Miguel Ibarra-Estrada[b,1], Alejandro González-Castro[c,1], Alejandra Cortés[d], Juan Núñez-Silveira[e]

[a] *Universidad de la Frontera, Critical Care Unit, Hospital Biprovincial Quillota-Petorca, Quillota, Chile*
[b] *Medicine of the Critically Ill, Civil Hospital Fray Antonio Alcalde and Instituto Jalisciense de Cancerología, Guadalajara, Mexico*
[c] *Intensive Care Service, Marqués de Valdecilla University Hospital, Santander, Spain*
[d] *Critical Care Unit, Hospital Biprovincial Quillota-Petorca, Quillota, Chile*
[e] *Terapia Intensiva del Hospital Italiano, Buenos Aires, Argentina*

[*] Corresponding author.
E-mail address: drauriopiotr@gmail.com (A. Fajardo-Campoverdi).
[1] WeVent®, International Mechanical Ventilation Group.

https://doi.org/10.1016/j.medin.2024.03.002