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LETTER

Mechanical power and driving pressure as predictors of mortality among patients with ARDS

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Dear Editor,

The postulated importance of mechanical power is that it provides a unifying concept combining the interaction of all the individual components of mechanical ventilation with the patient. Derived from the equation of motion, mechanical power calculates the energy delivered over time to the respiratory system by the ventilator [1]. Physiologically, mechanical power incorporates tidal volume, pressure, and additional parameters not included in driving pressure [2]. Previous studies demonstrated an association of power with mortality [3–5], but were primarily in non-ARDS populations [4], lacked consistent findings within all ARDS severities [3], or were unadjusted and descriptive of a single mechanical power threshold [5]. None assessed whether the association of mechanical power and mortality was independent from driving pressure.

To assess the relative strength of association of mechanical power and driving pressure (ΔP) with mortality, we pooled patients from three randomized controlled trials of ARDS. Methods are detailed in the Online data supplement, but briefly, we reconstructed the adjusted Cox proportional hazards model from the Amato et al. driving pressure [2] study (Table E1) and examined the relationship between ΔP with mortality, mechanical power with mortality, and, after checking for correlation and multicollinearity, we combined both ΔP and mechanical power in the same model. We also visually examined the relationship of ΔP and mechanical power with mortality. We analyzed patients not making respiratory efforts, and did a sensitivity analysis on patients making respiratory efforts.

We found that among 1294 patients without respiratory efforts (Figure E1, Table E2), ΔP was significantly associated, in adjusted analysis, with 60-day hospital mortality (hazard ratio [HR] 1.44 [95% CI 1.28, 1.62; $p < 0.001$]) (Table E2). Replacing ΔP with mechanical power, the HR was 1.39 (95% CI 1.28, 1.52; $p < 0.001$). Including *both* ΔP and mechanical power in the same model, each retained an independent significant relationship with mortality (ΔP: HR 1.2 [95% CI 1.03, 1.4; $p = 0.018$]; mechanical power: HR 1.26 [95% CI 1.11, 1.43; $p < 0.001$]) (Table E3). Sensitivity analyses among patients making respiratory efforts were unchanged (Table E6). Increasing quintiles of mechanical power, stratified on comparable levels of ΔP, were significantly associated with mortality (HR 1.19 [95% CI 1.1, 1.3; $p < 0.001$]) (Fig. 1a); the converse was also true (HR 1.12 [95% CI 1.03, 1.22; $p = 0.007$]) (Fig. 1b).

That mechanical power retains a significant relationship with mortality, despite adjusting for driving pressure, may be because mechanical power relies on other components than driving pressure itself. Clinically modifiable parameters such as flow and respiratory rate could also have an effect on mortality in ARDS patients. Like ΔP, mechanical power is normalized to individual compliance, but additionally includes respiratory rate and flow to quantify and include repetitive and dynamic forces. Mechanical power thus captures an applied

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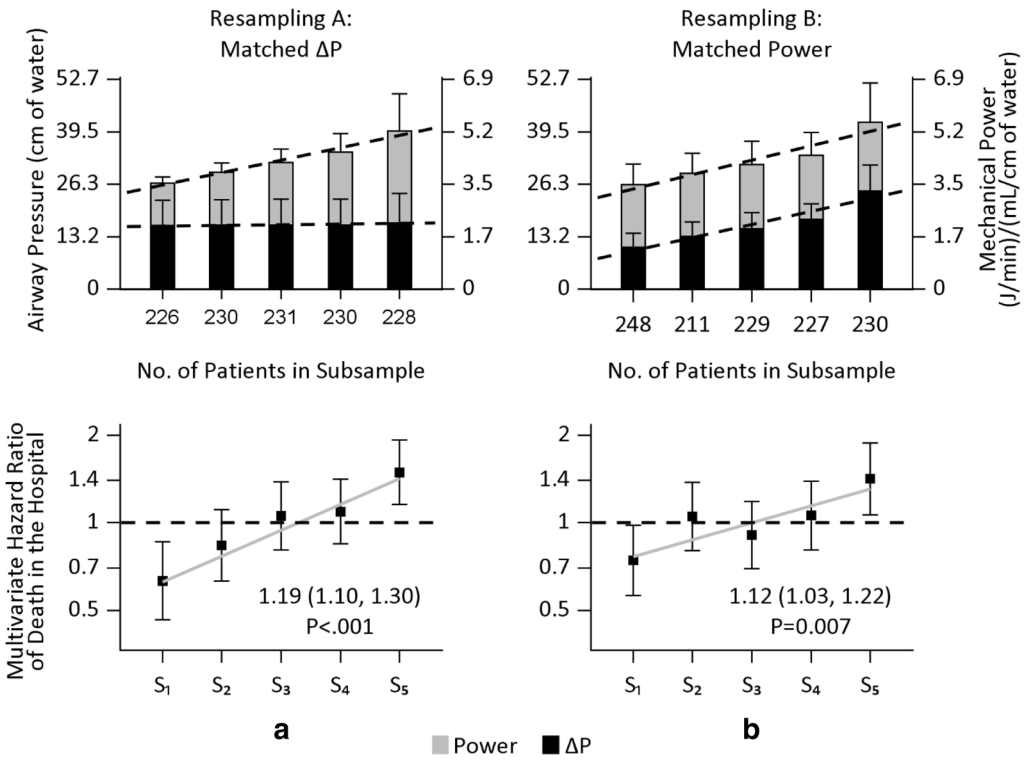

Fig. 1 Hazard ratio of in hospital death across relevant subsamples after multivariate adjustment. Multivariate adjusted hazard ratio of 60-day in-hospital death across patient strata. Strata in **a** (upper) have comparable values of driving pressure, but increasing values of mechanical power across strata. HR for each stratum is presented below. **b** Has comparable values of mechanical power, but increasing values of driving pressure across strata. Y1 axis is airway pressure; Y2 axis is mechanical power normalized to compliance. X axis reports cohort sample sizes

energy in a way that driving pressure does not. It provides additional risk estimation beyond driving pressure alone. Our results suggest a need for prospective interventional trials to examine the clinical effect of a mechanical power reduction ventilation strategy compared to either a tidal volume or to a driving pressure managed strategy.

Electronic supplementary material
The online version of this article (https://doi.org/10.1007/s00134-020-06130-2) contains supplementary material, which is available to authorized users.

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Authors' contributions
JT had full access to all the data in the study and takes responsibility for the integrity of the data, the accuracy of the data analysis, and the integrity of the submission as a whole, from inception to published article. JT, IP, SB, AP, HK conceived study design; JT, IP, SB, AP, JH, HK contributed to conduct of the study; JT, IP, JH, AP contributed to data acquisition and analysis; JT, AP, JH, HK drafted the work; all authors revised the article for important intellectual content, had final approval of the work to be published, and agree to be accountable to for all aspects of the work.

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Availability of data and materials

The data that support the findings of this study were obtained under license from the National Heart, Lung and Blood Institute (NHLBI) from the National Institutes of Health (NIH). Data were received de-identified in accordance with Section 164.514 of the Health Insurance Portability and Accountability Act (HIPAA).

Compliance with ethical standards

Conflicts of interest

None of the authors report any conflicts of interest related to this manuscript.

Code availability

To facilitate research reproducibility, replicability, accuracy and transparency, the associated analytic code is available on the Open Science Foundation (OSF) repository, [https://doi.org/10.17605/osf.io/rz863] [https://osf.io/rz863/].

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