ASSOCIATION OF MECHANICAL POWER WITH REINTUBATION IN THE CRITICALLY ILL: MACHINE LEARNING OUTPERFORMS LOGISTIC REGRESSION

Presenting Author: Kartikeya M. Menon BA, Icahn School of Medicine at Mount Sinai
Co-Authors: *Pranai Tandon MD, Hung-Mo Lin ScD, Yuxia Ouyang PhD, Matthew A. Levin MD*

Background: Mechanical power (MP) estimates the energy delivered to the lung parenchyma using respiratory rate, driving pressure, tidal volume, and peak pressure. Higher MP during ventilation has been correlated with greater risk of postoperative respiratory failure, as well as greater mortality in the critically ill and those with acute respiratory distress syndrome.[1,2] The existing literature examines this relationship with logistic regression. We hypothesized that a machine learning approach would better demonstrate the predictive ability of higher mechanical power with reintubation in critically ill patients.
Methods: Single-center retrospective study of medical intensive care patients intubated >48 hours at a tertiary care hospital from 2011-2019. MP (J/min) was calculated using the equation: $MP = 0.098 * RR * V_t * (PEEP + \Delta P)$. Two models predicting 72-hour reintubation were evaluated: a random forest (RF) classifier and logistic regression (LR). The data were split 80/20 for training/testing and synthetic minority oversampling was employed to adjust for class imbalance. Comorbidities included in the model were age, body mass index, rapid shallow breathing index (RSBI), intubation duration, P/F ratio, and level of consciousness. Demographics were assessed with the Mann Whitney test for continuous variables and ANOVA for categorical variables. Models were evaluated with sensitivity, specificity, F1 score, AUC, k-fold cross-validation, and odds ratios (ORs). For the LR, ORs were calculated by exponentiating log-odds coefficients. For the RF, ORs were imputed by computing individual conditional expectations (ICEs) for discretized MP ranges (<8, 8-13, 13-18, 18-23 J/min), and then transforming the average ICEs into probabilities via inverse logit. Feature saliency was assessed with mean decrease in impurity (MDI), a measure of how important a variable is to the information gain achieved by a node in a RF classifier.
Results: 894 patients met inclusion criteria, of which 136 (15.2%) required reintubation. Univariate analysis showed no statistically significant differences in comorbidities aside from RSBI (55.1 [38.7-88.6] vs 46.5 [28.8-71.6], p<0.01). The median MP was higher in the reintubation cohort (12.7 [10.0-16.2] J/min vs 11.8 [9.5-14.9] J/min, p<0.01) than in those who were successfully extubated. In the test set, traditional LR had a sensitivity of 25%, specificity of 64%, AUC-ROC of 0.52, AUC-PRC of 0.46, and F1 score of 0.32. In the test partition, the RF achieved a sensitivity of 55%, specificity of 76%, AUC-ROC of 0.71, AUC-PRC of 0.74, F1 score of 0.61. In the whole original data set, 10-fold cross-validation accuracy was 84.71% ± 0.01%. Feature analysis found peak MP (MDI=0.16) over duration of ventilation to be the most important variable, followed by median P/F (MDI=0.15) and median MP (MDI=0.15). The LR found the risk of reintubation to be 25% higher for each 5 J/min increase in median MP (OR 1.25, 95% CI 1.10-1.43, p<0.001). The RF-implied average reintubation risk per 5 J/min increase in median MP between 8 J/min and 23 J/mi was 20% (odds ratio 1.20, 95% CI 1.19-1.21, p<0.005).
Conclusion: Machine learning outperforms LR in predicting the association of higher peak and median mechanical powers with reintubation in critically ill patients. Further, the median MP delivered to ICU patients in this cohort is lower than values previously reported in the literature,[2] suggesting a correlation between MP and reintubation risk regardless of absolute MP value.

References

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