Review Article

The association of ventilator mechanical power with weaning outcomes in intensive care unit patients: a narrative review

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Background and Objective: Mechanical power (MP) provides an integrated index of the mechanical properties of the respiratory system during mechanical ventilation. Increased levels of MP may identify patients who will do poorly during weaning and extubation. This literature review investigated the use of MP as a predictor of weaning outcomes in intensive care unit (ICU) patients, including a focused comparison of patients with coronavirus disease 19 (COVID-19) infections and patients with other causes of respiratory failure.

Methods: A review of the literature using PubMed, Embase, MEDLINE, and Preprint identified 305 possible studies; after removal of duplicates, 219 studies were screened, and five papers were selected for analysis. A search updated in 2024 identified four additional papers to include in this review.

Key Content and Findings: These studies demonstrate that higher MP levels are associated with weaning failure in ICU patients and that adjustment of MP for lung-thorax compliance (LTC) improves the prediction of outcomes. One study analyzed outcomes in patients with COVID-19 infections and reported that despite having higher MPs, patients with COVID-19 had lower rates of weaning failures. This result suggests different respiratory mechanics in these patients that could complicate weaning decisions.

Conclusions: In summary, MP can predict weaning outcomes in patients with respiratory failure requiring mechanical ventilation. However, some patients with COVID-19 infection may have unusual respiratory mechanics that may influence these associations.

Keywords: Mechanical ventilation; weaning; extubation; mechanical power (MP)

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Introduction

Recent research has studied the concept of ventilator mechanical power (MP) as an index of lung mechanics (1,2). MP is a summary parameter derived from the respiratory rate, tidal volume (Vt), and the pressure needed to deliver the Vt (1). It quantifies the energy transferred from the ventilator to the patient's respiratory system during the respiratory cycle to overcome the elastic and resistive forces of the lungs and chest wall to provide adequate gas exchange. Higher levels of MP reflect more abnormal lung mechanics, and serial measurements of MP can help characterize changes in the mechanical properties of the lung during mechanical ventilation. These changes should reflect the clinical course of the underlying respiratory disorder and potentially could identify patients developing ventilator-induced lung injury. These measurements do not include any contribution of respiratory muscles in maintaining the minute ventilation.

Several investigators have measured MP prior to extubation to determine whether or not this parameter helps predict successful weaning and extubation, and these studies are analyzed in this review to determine this key question. We present this article in accordance with the Narrative Review reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-24-1381/rc).

Methods

Search strategy and selection criteria

A detailed search strategy was used with PubMed, Embase, MEDLINE, and Preprints to identify relevant studies to analyze the association between MP and weaning outcomes in patients requiring mechanical ventilation. The following search queries were used for each database to ensure a comprehensive literature capture. In PubMed, the search strategy included combinations of keywords and MeSH terms related to "ventilator" AND "mechanical power" AND ("spontaneous breathing trial" OR "weaning") and identified a large number of potentially relevant studies. In Embase, MEDLINE, and Preprints, queries used 'ventilator' (expanded) AND mechanical AND 'power' (expanded) AND 'weaning' (expanded), facilitating the identification of pertinent literature across these platforms. See Table S1.

The initial search identified 305 papers. After duplicates were removed and an initial screening, 219 papers were left for review. The screening and selection process was facilitated by using "new.rayyan.ai", a collaborative web-based platform designed to streamline the screening of articles for literature reviews.

Inclusion and exclusion criteria

Inclusion criteria were strictly defined to focus on studies conducted in intensive care units (ICUs), investigating the direct association between MP and weaning success during mechanical ventilation. Eligible studies were required to report relevant quantitative data and to be published in English. Exclusion criteria included reviews, case reports, conference abstracts, and studies on non-human subjects to ensure the review's relevance to clinical practice.

Study selection and data extraction

The selection of studies for inclusion was conducted by two independent reviewers who applied the inclusion and exclusion criteria. In cases of disagreement between the two primary reviewers regarding the eligibility of a paper, a third reviewer was consulted to make the final decision. This approach ensured a balanced and objective selection process. Data on study characteristics, MP measurements, and weaning outcomes were extracted from studies that met the inclusion criteria.

Search update

This search was updated on October 30, 2024, using the PubMed database. Four additional studies were identified that analyzed the association between MP and outcomes in patients requiring mechanical ventilation.

Results

Clinical studies on the use of MP in weaning predictions

Ghiani *et al.* retrospectively reviewed the outcomes of 263 patients with tracheostomies who required prolonged mechanical ventilation and were transferred to a specialized hospital in Germany (3). The investigators collected demographic and clinical information and ventilator parameters to determine which factors were associated with weaning success or weaning failure. Weaning failure was more frequent in obese patients, female patients, patients with chronic obstructive pulmonary disease (COPD), and patients with increased MP corrected for dynamic lung-thorax compliance (LTC). The MP was 18.4±5.3 Joules (J)/min in patients with weaning success and 21.2±6.1 J/min in patients with weaning failure. The MP corrected for ideal body weight was 252±79 ($\text{J/min/kg}\cdot 10^{-3}$) in patients with weaning success and 299±88 ($\text{J/min/kg}\cdot 10^{-3}$) in patients with weaning failure. The MP power corrected for dynamic LTC was 585±297 ($\text{J/min}\cdot\text{cmH}_2\text{O/mL}\cdot 10^{-3}$) and 777±366 ($\text{J/min}\cdot\text{cmH}_2\text{O/mL}\cdot 10^{-3}$), respectfully, in these two groups. When patients were classified according to the quartile of their MP power corrected for transthoracic dynamic compliance (Cdyn), there was an increase in weaning failure rates in each quartile. The failure rate was 25.8% in the first quartile and 67.7% in the fourth quartile. This study suggests that classifying patients based on ventilator parameters provides important information about their underlying respiratory disorders and can help predict the potential success of weaning and extubation. In addition, it is possible that designing chronic weaning programs based on these parameters may facilitate successful weaning by avoiding respiratory muscle fatigue and by changing treatment to improve lung mechanics when possible. This would require well-designed prospective studies.

In a second study, Ghiani *et al.* prospectively studied 130 patients with tracheostomies referred to a specialized hospital for weaning (4). They evaluated clinical and demographic factors and ventilator parameters to identify factors that were associated with weaning success. Patients with weaning failures were more likely to have a body mass index (BMI) greater than 30 kg/m^2, have had acute exacerbations of COPD as the initial cause of the acute respiratory failure, have renal insufficiency, or have COPD. Patients underwent structured weaning programs. Ventilator parameters were collected 48 hours after the first spontaneous breathing trial and 48 hours before the completion of the weaning program. Variables included dynamic LTC, MP, MP adjusted for ideal body weight, and MP adjusted for dynamic lung-thoracic compliance. In addition, MP adjusted for dynamic lung-thorax compliance (LTCdyn-MP) was adjusted to ventilator settings that provided an optimal pCO$_2$, referred to as a power index (PI). The threshold value for predicting weaning failure was 20.3 J/min. LTCdyn-MP predicted weaning success with a positive likelihood ratio of 3.3 and a negative likelihood ratio of 0.3. The area under the receiver operating curve was 0.86 [95% confidence interval (CI): 0.78–0.91]. This study demonstrates that MP can help predict weaning success, and it was based on prospective data collection.

In a third study, Ghiani *et al.* analyzed clinical factors and ventilator parameters that were associated with failure of the initial spontaneous breathing trials in 130 patients with chronic respiratory failure and tracheostomies who were referred to a specialized weaning center (5). The mean MP in all patients was 21.0±5.9 J/min; 30 patients failed their first spontaneous breathing trial defined by clinical parameters measured during the trials which included increased respiratory rates (>35 breaths per minute), increased heart rates (>130 beats per minute), increased systolic blood pressures (>160 mmHg), and low O$_2$ saturations (<88%). Patients with smoking histories, acute exacerbations of COPD resulting in mechanical ventilation, and histories of COPD had increased frequency of failure. Ventilator parameters associated with failure included PaCO$_2$, peak airway pressure required for ventilation, driving pressure, dynamic lung compliance, MP, MP adjusted for ideal body weight, and LTCdyn-MP. None of the variables had a positive likelihood ratio greater than 3. The area under the receiver operating curves for MP was 0.68 (0.59–0.75), for MP adjusted for ideal body weight was 0.71 (0.62–0.79), and for MP adjusted for dynamic thoracic compliance was 0.76 (0.68–0.83). In a multivariable analysis, MP and its adjustment for either ideal body weight or transthoracic compliance were statistically significant in three separate models. The PaCO$_2$ during mechanical ventilation was significant in all three models. This study demonstrates that MP can predict the success of a spontaneous breathing trial. This information could help clinicians identify patients who need more clinical assessment.

In a fourth study, Ghiani *et al.* analyzed changes in the ventilatory ratio and the MP in 249 patients, including 53 patients who had had coronavirus disease 19 (COVID-19) infections, who required prolonged mechanical ventilation, and who had undergone tracheostomies (6). Measurements were made before the first spontaneous breathing trial on admission, 48 hours after the first spontaneous breathing trial, and 48 hours before weaning completion. Patients with histories of COVID-19 infection had higher ventilatory ratios, MPs, and power indices on each of the study days. The median MP was 24.2 J/min [interquartile range (IQR), 20.8–28.6 J/min] in patients with prior COVID-19 infections and was 20.1 J/min (IQR, 17.1–24.4 J/min) in the other patients at weaning completion. The probability of survival was increased in patients with prior COVID-19 infections. Using multivariable regression analysis, an increased BMI, the diagnosis of COPD, and increased PI were associated with weaning failure. The diagnosis of COVID-19 pneumonia was associated with a decreased likelihood of weaning failure. Therefore, the MP cut points for success may depend on the underlying cause of respiratory failure.

Ghiani *et al.* recently published a prospective cohort study with 140 patients with tracheostomies and respiratory failure in which they analyzed MP density and spontaneous breathing indices as predictors of weaning success (7). The spontaneous breathing indices included Vt normalized to predicted body weight, rapid shallow breathing index, and an integrative weaning index. The diagnostic accuracy of these indices was calculated at the start and the end of a standardized weaning protocol. Weaning failure occurred in 41 patients (29%), and these patients had significantly higher MP densities, lower Vts per predicted body weight, higher rapid shallow breathing indices, and a lower integrated weaning index. MP density was more accurate in predicting weaning failure than the traditional indices calculated during a spontaneous breathing trial, and it had an area under the curve of 0.91. The MP density in this study was calculated by multiplying the energy density or energy per breath normalized to Cdyn times the respiratory rate, resulting in the energy transferred per minute with respect to the volume delivered per minute. The formula is:

$$\mathrm{LTC}_{\mathrm{dyn}} - \mathrm{MP}\left[\mathrm{cmH_2O^2/min}\right] = \mathrm{RR} \times \mathrm{P}_{\max} \times \mathrm{delta}\ \mathrm{P}_{\mathrm{aw}} \qquad [1]$$

where RR is respiratory rate, P_{max} is peak inspiratory pressure, delta P_{aw} is dynamic driving pressure.

Ghiani *et al.* also studied MP density in patients who had just undergone double lung transplantations (8). These indices were calculated up to 36 hours post transplantation and correlated with the duration of invasive ventilation in the patients; 82 patients (35% of 237) required prolonged mechanical ventilation defined as greater than 72 hours. Ventilatory variables (PaO_2/FiO_2 and dynamic lung-thorax compliance) and MP indices were analyzed to determine which variable best predicted the duration of post-transplant invasive ventilation. MP normalized to lung-thoracic compliance had the best correlation (Spearman correlation coefficient =0.452, $P<0.01$). The sensitivity of this parameter was 0.71, the specificity was 0.74, the positive likelihood ratio was 4.6, and the negative likelihood ratio was 0.4. Consequently, this study indicates that the early measurement of MP post lung transplantation could help predict the duration of prolonged mechanical ventilation in this group of patients. This approach should also be studied in other patient groups, such as acute respiratory distress syndrome (ARDS), intubated for acute respiratory failure.

The MP calculated in the studies by Ghiani *et al.* used this equation:

MP (Joules/min) =0.098 × Vt × RR × P_{max} on a pressure-controlled mode. The spontaneous breathing trials in these patients used a T-piece with oxygen supplementation.

Yan *et al.* analyzed the association between MP and weaning outcomes in critically ill patients who required mechanical ventilation (9). They downloaded information from the Medical Information Mart for Intensive Care IV (version 1.00) that contains information on 76,540 ICU admissions at Beth Israel Deaconess Medical Center in Boston between 2008 and 2019. They collected information on patients who are older than 18 and required mechanical ventilation for at least 24 hours. The criteria for a weaning trial included a T-tube test, which lasted between 30 and 120 minutes on the same FiO_2 that the patient was currently being ventilated on prior to the test. They collected information on ventilator parameters, MP, dynamic lung compliance, dynamic driving pressure, MP corrected for dynamic LTC, and MP corrected for predicted body weight. The study cohort eventually included 3,695 patients who completed spontaneous breathing trials that were recorded in the data set. The failure rate at the end of the first spontaneous breathing trial was 38.5%. The reintubation rate, or the requirement for noninvasive mechanical ventilation, or death within 48 hours of the first successful spontaneous breathing trial was 11.1%. Patients with weaning failure had higher plateau pressures, peak pressures, respiratory rates, minute ventilations, MP, Cdyn, MP adjusted for Cdyn, and MP adjusted for predicted body weight. The MP levels were 9.2 (6.0–13.2) J/min in the successful weaning patients and 14.6 (10.6–20.2) J/min in the weaning failure patients. The 28-day mortality rate was higher in the weaning failure group.

Three models were used to determine the variables associated with weaning failure, and in these three models, MP, MP adjusted for Cdyn, and MP adjusted for ideal body weight were all increased in patients with weaning failure. When patients were classified according to successes, 1 failure, 2 failures, or 3 failures, the MP progressively increased in each failure group. The same pattern was seen in MP adjusted for Cdyn and adjusted for predicted body weight. Finally, when MP was calculated at 4-hour intervals for 24 hours prior to the spontaneous breathing trial (SBT) to determine the trend, it decreased in patients who had a successful trial and did not change in patients who had an unsuccessful or failed trial. The authors concluded that MP power was associated with weaning outcomes in critically ill, mechanically ventilated patients. This study used a very large database and analyzed several important ventilator parameters. Consequently, it may reasonably reflect outcomes in the "average" ICU patient on ventilators.

Yan *et al.* [2024] reanalyzed the outcomes of 3,695 patients in the above database who required invasive mechanical ventilation for at least 24 hours and underwent a weaning trial using a T-tube strategy with the primary focus on the utility of MP adjusted for dynamic lung compliance in weaning outcomes (10). The median duration of invasive mechanical ventilation was 3.7 days. Multiple clinical variables and respiratory variables were collected and analyzed in these patients 4 hours before the spontaneous breathing trial. MP was normalized to dynamic lung compliance [Vt/(peak pressure − PEEP); Cdyn-MP]. The overall incidence of weaning failure was 38.5% (1,421 out of 3,695 patients). This increased from 7.6% in patients in the first quartile of MP corrected for dynamic lung compliance to 63.6% in patients in the fourth quartile. In multivariate regression analysis with Cdyn-MP analyzed in quartiles, the odds ratio for weaning failure was 5.05 in the second quartile, 8.27 in the third quartile, and 10.37 in fourth quartile. These authors concluded that an increased

Table 1 Mechanical power and ventilator weaning

Study	Study population	Key findings
Ghiani *et al.* (3), 2020	General ICU patients, prolonged MV with tracheostomy (N=263)	Higher inspiratory positive airway pressure, driving pressure, ventilatory ratio, absolute MP, and MP normalized to predicted body weight and to dynamic lung-thorax compliance were associated with unsuccessful weaning. LTCdyn-MP identified as an independent predictor of weaning failure
Ghiani *et al.* (4), 2021	General ICU patients (N=130). Prospective study	Absolute MP showed poor discrimination in predicting weaning outcomes; LTCdyn-MP had moderate diagnostic accuracy. The PIrs significantly improved discriminatory ability
Ghiani *et al.* (5), 2022	General ICU patients (N=130)	Absolute MP had poor discriminatory ability to predict SBT outcomes, which improved with LTCdyn-MP. Including $PaCO_2$ (PIrs) further improved discriminatory ability
Ghiani *et al.* (6), 2023	ICU patients (COVID-19: 53; non-COVID-19: 196)	COVID-19 patients had higher VR and MP compared to those with other etiologies but had a significantly lower rate of weaning failures and higher dynamic lung-thorax compliance, indicating unique respiratory mechanics
Ghiani *et al.* (7), 2024	Patients with tracheostomy (N=140)	MP density predicted weaning failure better than parameters derived during the spontaneous breathing trial
Yan *et al.* (9), 2022	General ICU patients (N=3,695)	Higher LTCdyn-MP was significantly associated with weaning failure. A threshold value above which the likelihood of weaning failure significantly increased was identified
Yan *et al.* (10), 2024	General ICU patients (N=3,695)	Increased LTCdyn-MP before a SBT predicted weaning failure

ICU, intensive care unit; MV, mechanical ventilation; COVID-19, coronavirus disease 19; MP, mechanical power; LTCdyn-MP, MP adjusted for dynamic lung-thorax compliance; PIrs, power index for respiratory system; VR, ventilatory ratio; SBT, spontaneous breathing trial.

Cdyn-MP measured before a spontaneous breathing trial was associated with a higher risk of weaning failure.

The MP in the Yan studies was calculated using this equation: MP (joules/min) =0.098 × Vt × RR × $[P_{peak} - 0.5 \times (P_{plat} - PEEP)]$. The spontaneous breathing trials in this study used a T-piece with oxygen supplementation.

Pan *et al.* [2023] analyzed the variability in respiratory parameters in patients before extubation (11). This involved continuous ventilation waveform analysis for 1 hour during SBTs on a pressure support of 6 cmH_2O and a positive end expiratory pressure (PEEP) level of 6 cmH_2O before extubation. They collected information on the peak inspiratory pressure, respiratory rate, Vt, minute ventilation, rapid shallow breathing index, MP per breath, MP per liter ventilation, and MP per minute. Using complex computer analysis, they calculated the basic and complex variability of these parameters, including the standard deviation, coefficient of variation, Poincare´ analysis, and entropy analysis. This study included 163 patients with 12 extubation failures; all patients had passed this SBT before extubation. Patients with successful extubation had the highest coefficient of variation for MP per breath; the area under the receiver operating curve was 0.777. The authors suggested that information derived from the variation in MP per breath provides more information about the physiological status of the patient prior to extubation than a single measurement of these parameters. Increased variability presumably reflects increased detection and response to breath-to-breath differences in the work of breathing and other physiological parameters that control respiratory responses and maintain homeostasis (12,13).

These studies demonstrate calculation of MP before a spontaneous breathing trial can help identify patients who will do poorly (*Table 1*). The Pan study also demonstrates that increased variability in MP during a spontaneous breathing trial is associated with an increased likelihood of extubation success. In addition, serial measurement of MP can help define the clinical course of patients and potentially lead to reassessment of current management strategies, if the level is high.

Discussion

Other considerations in the use of MP during mechanical ventilation

This narrative review considers the potential use of MP as a predictor of weaning outcomes during mechanical ventilation. The research conducted by Ghiani *et al.* and Yan *et al.* demonstrates an important association between MP adjusted for LTC and weaning success and indicates that higher adjusted MP levels are associated with an increased likelihood of weaning failure (3-6,9). These results help identify patients with more abnormal lung mechanics who may not tolerate the increased work of breathing after extubation. These results also suggest that MP should be monitored during mechanical ventilation as another index of lung stress, and the lack of improvement, i.e., a decrease, may indicate persistent lung injury and also the potential for ongoing ventilator-induced lung injury. Conversely, decreases in MP reflect improvement in lung mechanics and presumably recovery from the acute deterioration in respiratory status. The primary focus on non-COVID-19 patients in this review underscores the general applicability of MP as a predictive marker for weaning outcomes and supports its consideration in the management of mechanically ventilated patients. The adjustment of MP for LTC provides a composite index of ventilator work and thoracic compliance, which includes the effect of the chest wall and abdomen on the work of breathing. This parameter may provide a good indicator of the patient's readiness for weaning and possibly can guide adjustments in ventilatory support needed by the patient prior to weaning during prolonged mechanical ventilator support.

Mechanical properties in COVID-19 lungs

Ghiani compared weaning outcomes in patients with COVID-19 infections with patients with other causes of respiratory failure requiring mechanical ventilation (6). This information offers an additional perspective on the complexity of weaning outcomes. This study found that patients with higher ventilation ratios and MPs had lower rates of weaning failures and supports studies that have suggested that COVID-19-related respiratory failure may involve unusual respiratory mechanics that might affect weaning differently than other causes of respiratory failure. Moreover, the additional insights from COVID-19 patients highlight the need for more research to understand the distinct respiratory mechanics associated with COVID-19 and their implications for mechanical ventilation and weaning strategies. Understanding these differences is necessary to develop tailored approaches that can accommodate for the unique challenges presented by COVID-19 infections and possibly improve weaning success rates and patient outcomes in this heterogeneous patient population. In addition, there may be other disorders causing respiratory failure with different average MP levels, which would influence weaning outcomes when compared to a heterogeneous group of patients often managed in ICUs. This concern would require studies of well-characterized patients with uniform clinical and radiologic diagnoses.

Approaches to and guidelines for weaning

The decision to discontinue mechanical ventilation and extubate patients requires assessment of the clinical course and recovery from the episode of acute respiratory failure and an assessment of the patient's ability to sustain spontaneous respiration. This requires a bedside assessment of the respiratory status, cardiac status, level of consciousness, and muscular strength. The American Thoracic Society and the American College of Chest Physicians have created a "Clinical practice guideline for liberation from mechanical ventilation and critically ill patients" (14,15). This guideline emphasizes early mobilization, the use of protocol for liberation from mechanical ventilators, cuff leak checks, and the addition of corticosteroids if there is no cuff leak. Pham *et al.* reported the results from a WEAN SAFE study, which was an international multicenter prospective cohort study that involved 481 ICUs and 50 countries (16). This study eventually enrolled 5,869 patients, and 3,523 patients underwent at least 1 weaning protocol. Overall, 3,817 patients (65.0%) were successfully weaned from mechanical ventilation by day 90. This study demonstrates that many patients do not recover from an episode of acute respiratory failure and suggests that higher sedation scores and delayed initiation of weaning were associated with weaning failure. Consequently, the management of weaning requires the full attention of the ICU team. For example, Nitta *et al.* used a comprehensive protocol for ventilator weaning and extubation (17). This protocol included four consecutive checklists to make decisions about extubation and post-extubation respiratory support. In this study, 464 patients required mechanical ventilation for >48 hours; 248 patients were included in the final analysis. Two hundred and twenty-four patients had successful extubation, 24 (9.7%) had post-extubation respiratory failure, and 13 (5.2%) required reintubation. These results suggest that a comprehensive check list approach based on bedside protocols can have very good outcomes.

Clinical factors that affect weaning success

Other studies have reviewed specific factors that might limit weaning success. Sanfilippo *et al.* reported a systematic review and meta-analysis of studies that included information from echocardiography in patients undergoing weaning (18). This study reported that left ventricular diastolic dysfunction was associated with weaning failure, but the effect of systolic dysfunction was uncertain. Vivier *et al.* studied diaphragm function using ultrasound in patients undergoing spontaneous breathing trials and determined that diaphragm dysfunction measured by decreased excursion and decreased thickening was not associated with an increased risk of extubation failure (19). Aldabayan *et al.* prospectively studied weaning success in patients with COVID-19 infections (20). This study included 90 patients, and 50 were successfully weaned. Factors associated with weaning success included Cdyn, lymphocyte count, urine output, and alanine aminotransferase levels. Three of these factors reflect inflammation, renal function, and liver injury, i.e., systemic disorders, and their importance is related to the COVID-19 infection rather than to the presence of acute respiratory failure. Menguy *et al.* used data mining and artificial intelligence to identify factors that predicted successful weaning (21). This study included 108 patients who underwent 135 spontaneous breathing trials; the Early-Warning Score-Oxygen, mean arterial pressure, heart rate variability, BMI, and occlusion pressures at 0.1 seconds helped predict weaning success. These parameters are complicated and do not just involve the respiratory system. These studies demonstrate that the factors associated with post-extubation respiratory failure are potentially more complicated than just factors involving lung function and reflect the importance of an integrated assessment of the patient's clinical status at the time this decision is made.

Models for weaning prediction

Important bedside parameters include level of oxygen support and the rapid shallow breathing index during a spontaneous breathing trial. Measurement of MP provides an additional index of lung mechanics, and higher levels of MP are potentially associated with increased work of breathing post-extubation, respiratory muscle fatigue, and eventually respiratory failure. Yan *et al.* analyzed the Medical Information Mart for Intensive Care-IV (version 1) to develop a prediction model for weaning failure in mechanically ventilated patients (22). This large database was split into a development cohort (n=2,586) and a validation cohort (n=1,109). Multivariate regression analysis indicated that positive end-expiratory pressure, dynamic lung compliance, MP, inspired oxygen concentration, length of ICU stays, and length of mechanical ventilation were independent predictors of weaning failure. The area under the receiver operating characteristic curve for the prediction model was 0.828 (0.8120–0.844). Critical values in this model included a PEEP level ≥8 cmH$_2$O, MP level ≥15 J/min, and Cdyn ≤30 mL/cmH$_2$O, an FiO$_2$ >40%, the number of ICU days ≥7, the number of mechanical ventilation days ≥3. MP ≥15 J/min was assigned 100 points in this model. The probability of weaning failure was approximately 40% in patients who had 250 points in this model.

Limitations

This review provides information about the association between MP and weaning outcomes in ICU patients, but it does have limitations that might affect the interpretation of these results. First, this analysis was based on a small number of studies that met the inclusion criteria. This limitation might restrict the generalizability of the conclusions across all ICUs and mechanical ventilation management approaches. Second, these studies included a wide range of patient populations, including those with COVID-19 and various other etiologies of respiratory failure. While this diversity potentially provides information about a range of patients requiring mechanical ventilation, it also introduces variability in terms of underlying health conditions, ventilation strategies, and weaning protocols, and this complicates the direct comparison and synthesis of results. Third, there is no standardized method for calculating or reporting MP in studies on MP. Differences in measurement techniques and the specific parameters included in MP calculations could lead to variability in reported values, affecting the comparability of studies. Fourth, as with any literature review, there is a risk of publication bias, in which studies with positive or significant findings are more likely to be published than those with negative or inconclusive results. Fifth, most included studies are cross-sectional or retrospective, providing information patient outcomes at specific time points. Longitudinal studies are needed to track patients over time to better understand the long-term impact of MP results on weaning success and recovery. Sixth, the review was limited to studies published in English and may have omitted relevant research reported in other languages. Seventh, the investigators in these studies did not consider the hemodynamic status or respiratory muscle function in these weaning trials.

Future research

There is a need for prospective studies that monitor MP in real-time, assessing its predictive value for weaning outcomes. Such studies should aim to establish causality and determine whether interventions to optimize MP can directly improve weaning success rates.

More research is needed to understand the mechanisms by which MP influences lung injury and the weaning process. Experimental studies could explain the physiological impact of varying MP levels on lung tissue, particularly in the context of COVID-19, which can have unique respiratory mechanics. Considering the pivotal role of SBTs in the weaning process, focused research on the relationships between MP and successful SBT outcomes is essential. Understanding how MP adjustments can enhance SBT success rates could significantly advance weaning protocols and improve patient outcomes.

Conclusions

In conclusion, the studies involving non-COVID-19 patients provide a foundation for understanding the role of MP in predicting weaning success; the observations related to COVID-19 patients introduce an additional dimension to this complex relationship. These results suggest that MP could serve as an important predictor of weaning success, offering a quantitative parameter to guide the adjustment of ventilatory support. Future research should continue to analyze MP adjusted for LTC in different patient groups, especially patients with frequent causes of respiratory failure in ICU to refine weaning strategies and possibly improve outcomes in mechanically ventilated patients. Medical equipment companies that manufacture ventilators should include the calculation of MP in the software so that this information is easily and continuously available.

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Footnote

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