LIMITING THE IMPACT OF RESPIRATORY MUSCLE DYSFUNCTION (RMD)

Managing the respiratory muscle strength of mechanically ventilated patients can significantly influence ventilator liberation. Use this evidence guide to learn more about the etiology, consequences, and management of respiratory muscle dysfunction.
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WHAT IS RESPIRATORY MUSCLE DYSFUNCTION?

Respiratory muscle dysfunction is a common complication of mechanical ventilation in intensive care unit (ICU) patients.

- Goligher et al. found using ultrasound that diaphragm thickness decreased more than 10% in 41% of patients after four days of mechanical ventilation.\(^1\)
- Similarly, Jaber et al. documented a 32% decrease diaphragmatic airway occlusion pressure in mechanically ventilated patients at day 6.\(^2\)

The onset of respiratory muscle dysfunction is surprisingly rapid. Grosu et al. demonstrated reductions of diaphragmatic thickness begins within 48 hours of the initiation of mechanical ventilation.\(^3\)

Respiratory muscle weakness may persist well after liberation from mechanical ventilation.

- 7 days post ICU discharge, inspiratory muscle dysfunction was still present in 69% of type 1 respiratory failure patients who were mechanically ventilated.\(^4\)
- Patients who suffered inspiratory muscle dysfunction were significantly more likely to be readmitted to ICU within 45 days of ICU discharge.\(^4\)
- Additionally, respiratory muscle dysfunction is associated with increased risk for mortality at one year.\(^5\)

The consequences of respiratory muscle dysfunction are significant. Suffering diaphragm thickness reductions of >10% is associated with:

- Lower daily probability of liberation from ventilation (adjusted hazard ratio, 0.69 per 10% decrease).\(^1\)
- Prolonged ICU admission (adjusted duration ratio, 1.71).\(^1\)
- Higher risk of complications (adjusted odds ratio, 3.00).\(^1\)
PREVENTING RESPIRATORY MUSCLE DYSFUNCTION

Studies have demonstrated that mechanical ventilation modes that allow for partial support of breathing are able to reduce atrophy and reduce many of the negative effects of controlled mechanical ventilation. Pressure support ventilation (PSV) is a widely used mode of assisted mechanical ventilation where a preset level of pressure is maintained by the ventilator and the patient is able to initiate the mechanical breath, change the inspiratory flow, and regulate their own respiratory rate and tidal volume as determined by their muscular efforts. However, asynchrony between the patient and ventilator may occur with PSV because patient conditions are constantly changing and can vary from breath to breath.

The proportional assist ventilation (PAV+) software has been considered as an alternative mode to PSV for facilitating spontaneous breathing while limiting the adverse effects of patient-ventilator asynchrony. Unlike PSV, the PAV+ software does not require a preset airway pressure, flow, or volume and the responsibility of guiding the ventilatory pattern is shifted completely from clinicians to patients, with the purpose of improving the patient-ventilator interaction.

In a study of 53 mechanically ventilated patients, Carteaux et al. maintained patients’ respiratory muscle pressure-time product between 50 and 150 cm H2O·s/min for 79% of the time with only one gain adjustment per patient per day via an algorithm to adjust the PAV+ mode gain to target a predefined respiratory target. Using this methodology, the PAV+ software may allow patients to engage in spontaneous breathing without a high work of breathing, which may limit respiratory muscle atrophy or fatigue.

For more information on Carteaux’s methodology for calculating respiratory muscles engagement, please see the Pmus calculator.

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PREVENTING RESPIRATORY MUSCLE DYSFUNCTION (CON’T)

Compared to PSV, the PAV+™ software has been demonstrated to reduce the likelihood of respiratory muscle dysfunction by:

- Increasing the portion of respiratory workload shared by the patient, which may aid in strengthening the respiratory muscles, while reducing respiratory distress. \(^\text{12}\) Peak airway pressure (p < 0.005) and area under the inspiratory pressure curve (p < 0.0005) (measures of ventilator assistance) and respiratory distress (p=0.002) in 50 patients randomized to receive the PAV+™ software or PSV. \(^\text{12}\)

- Reducing the likelihood that patients revert to a controlled mode due to respiratory distress, hypoxemia, hypercapnia, severe hemodynamic instability, or increased need for sedation (Failure rate) \(^\text{18}\). Failure rate in patients (n=208) randomized to receive the PAV+™ software or PSV (p=0.04) \(^\text{18}\).

- Reducing respiratory workload \(^\text{16}\). Transdiaphragmatic pressure–time product per minute of ventilation in patients randomized to receive the PAV+™ software or PSV under imposed load condition (p<0.05) \(^\text{16}\).

- Reducing patient-ventilator asynchrony \(^\text{17}\). Patient-ventilator asynchrony events per hour of sleep in patients randomized to receive the PAV+™ software or PSV (p=0.02) \(^\text{17}\).
RESPIRATORY MUSCLE RECOVERY AND WEANING IN PATIENTS SUFFERING FROM RESPIRATORY MUSCLE DYSFUNCTION

RMD has been shown to be associated with weaning failure. Therefore where RMD is the underlying cause of weaning failure, patients may benefit from strategies that gradually engage and strengthen the respiratory muscles. As the PAV+™ software allows patients to share a greater portion of the respiratory workload while having less episodes of respiratory distress compared to PSV, clinicians are investigating using the PAV+™ software as a tool to reengage the respiratory muscles while limiting stress in difficult to wean patients. Elganady et al. determined that among weaning failure patients, receiving the PAV+™ software resulted in reduced time on mechanical ventilation, ICU length of stay, and hospital stay. Additionally, Al Gawzi et al utilized the PAV+™ software to liberate 14 prolonged mechanical ventilation patients (mean duration of MV was 53.2 days prior to PAV+™ software). Once placed on the PAV+™ software, the patients’ negative inspiratory force and airway occlusion pressure improved by 87% and 79% respectively. All patients were successfully extubated, with a mean time to extubation of 5.8 days. For more information on technique to integrate PAV+™ software into the treatment of difficult to wean patients, see the prolonged weaning protocol from St. Mary’s Hospital in Kitchener, Ontario, Canada.
PROLONGED WEANING PROTOCOL

St. Mary’s Hospital in Kitchener, Ontario, Canada.

Purpose

- To provide standard guidelines for the reduction in ventilatory support to minimal levels to wean a patient from mechanical ventilation

Background

- Weaning from mechanical ventilation can be a complex undertaking. It can vary from a rapid process of a few minutes to one that proceeds over a period of days or weeks. Several studies over the past few years have shown that weaning from mechanical ventilation is dependent on the use of a standard method for the weaning process. Other studies have also shown that using a non-physician driven weaning routine by the bedside care givers (i.e. Respiratory Therapists) results in shorter intubation/ventilation times and may result in shorter ICU and hospital lengths of stays.

- In the last 20 years the gold standard for weaning from mechanical ventilation has been using a spontaneous mode of ventilation with Pressure Support (PS) as the inspiratory assistance to reduce the work of breathing for the patient. The PS model usually involves routinely decreasing the amount of PS by small amounts daily until the patient reaches minimal levels of support and is extubated, or has an increase work of breathing at which time the PS is increased to make the patient more comfortable. Comparative studies using PS, T-piece weans, slowly decreasing a set respiratory rate on SIMV ventilation and even the early mode of proportional assist ventilation (PAV) have been performed. While showing that the decreasing RR on SIMV mode promoted longer intubation times, there was no clear best model of weaning among the other modalities.

- With improvements in the computer processors in ventilators, new modes of ventilation have become available that are much more responsive to a patient’s changing demands. In PS a preset amount of pressure is applied to the breathing circuit once the patient meets the inspiratory criteria set by the ventilator, regardless of the patient’s changing efforts and does not require the patient to continue the inspiratory effort to receive a breath. The new modes of ventilation such as the next generation of proportional assist ventilation (PAV+) and neurally adjusted ventilatory assist (NAVA) assess and adapt to a patient’s changing respiratory efforts and demands. They require the patient to remain fully involved in the inspiratory efforts to get and maintain a breath. Early studies with both PAV+ and NAVA show earlier improvements in respiratory muscle strength rebuilding and potential decreased intubation times and complications associated with mechanical ventilation. Comparative head to head trials with these modes and PS are currently underway at multiple centers.

- The premise of this protocol is to use PAV+ as a weaning tool to retrain and strengthen the respiratory muscles sooner. Having the respiratory muscles contribute to the entire inspiratory phase and not just initiating a breath, we are increasing the work they are doing. Combining this with frequent, repetitious work and rest cycles similar to peripheral muscle conditioning routines, the goal is to reduce the time spent on a ventilator and lower the risk of the patient developing secondary complications of intubation and ICU stays.
PROLONGED WEANING PROTOCOL (CON’T)

St. Mary’s Hospital in Kitchener, Ontario, Canada.

Procedure

1. Phase I - Assessment

   a.) The RT will place the patient on spontaneous mode of ventilation with PAV+ at 80% support. If the patient requires more than 80% support, the RT will return the patient to their previous mode of ventilation and PAV weaning will be reattempted the next day.

   b.) PAV+ will be the primary mode for resting the patient during the weaning process to provide the support they need, but to also maintain some work from the respiratory muscles. A PAV of 80% support will be the patient’s resting PAV level. The RT will consider reducing the resting PAV level only if the patient’s tidal volume is too high, or their respiratory rate too low. If PAV+ is not tolerated or is contra-indicated (see Special Circumstances, Section 5), consider other supportive modes before proceeding to controlled modes of ventilation for rest.

   c.) The RT will place the patient on PAV+ of 35% support for 30 minutes. If the patient tolerates the PAV trial, the RT will extend the patient’s trial until the patient develops respiratory fatigue. A PAV of 35% support will then become the patient’s trial PAV level. The length of time for respiratory fatigue to occur will become the initial trial length for the chart below.

   d.) If the patient does not tolerate a PAV of 35% support for 30 minutes, the RT will rest the patient until the next day and reattempt the PAV trial with a level of support 10% higher than the previous day.

   e.) The PAV support level will be increased by 10% each day until the patient is able to remain on the trial for a minimum of 30 minutes. The PAV support level required will become the patient’s trial PAV level. The length of time before respiratory fatigue develops will become the patient’s initial trial length.
PROLONGED WEANING PROTOCOL (CON’T)

St. Mary’s Hospital in Kitchener, Ontario, Canada.

2. Phase II - PAV Wean

a.) The RT will reduce the PAV support to the patient’s trial PAV level (determined in Phase I) in trials of increasing length, followed by periods of rest.

<table>
<thead>
<tr>
<th>Length</th>
<th>Frequency</th>
<th>Total Trial Time</th>
<th>Rest Between Trials</th>
<th>Rest PAV Level</th>
<th>Rest Overnight</th>
</tr>
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<tbody>
<tr>
<td>30 min</td>
<td>4</td>
<td>2 hours</td>
<td>2 hours</td>
<td>80%</td>
<td>2200-0800</td>
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<tr>
<td>1 hour</td>
<td>3</td>
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<td>2 hours</td>
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<td>12 hours</td>
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<td>12 hours</td>
<td>N/A</td>
<td>80%</td>
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<tr>
<td>16 hours</td>
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<td>16 hours</td>
<td>N/A</td>
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b.) The RT will monitor the patient for intolerance/exit criteria or accelerated wean pattern and adjust the weaning plan as necessary.

Exit Criteria

- RR > 35 for > 5 minutes: respiratory distress and/or accessory muscle use
- SpO₂ < 88%: mental status change
- HR ↑ 20% for > 5 minutes: acute cardiac arrhythmia
- BP ↑ 20% for > 5 minutes: EtCO₂ ↑ ≥ 15 mmHg from baseline

c.) An accelerated wean will be considered if the f/Vt ratio remains ≤ 70-80 at the end of each trial. The RT may accelerate the weaning by advancing the patient to the next step in the weaning chart for their last trial of the day.

d.) If the trial PAV+ support level determined is >60%, once 16 hours have been completed, the RT will begin again at a PAV level of 35% support as per step (c). The patient will rest on a full support mode overnight and in between trials.

e.) RT will document the results of each day’s wean.

f.) Patient must complete 16 hours of PAV 35% support before moving to phase III.
PROLONGED WEANING PROTOCOL (CON’T)

St. Mary’s Hospital in Kitchener, Ontario, Canada.

3. Phase III - Corking/PMV/T-piece Wean
   a.) The RT will cork the patient during Phase III trials to allow phonation and the use of vocal muscles and swallowing reflexes.
   b.) The RT will consider a speaking valve if the patient does not tolerate corking (in conjunction with the Speech Language Pathologist if available).
   c.) The RT will consider using the Optiflow trach adaptor if neither corking, nor speaking valve are tolerated, but patient has a tendency to derecruit lung volumes, or has thick secretions.
   d.) The RT will deflate tracheostomy tube cuff and initiate the cork/speaking valve or initiate t-piece with cuff up and ensure patient comfort and oxygenation.
   e.) The RT will increase the length of corking/speaking valve trials or t-piece trials each day, resting the patient in-between.

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f.) RT will monitor the patient for intolerance/exit criteria or accelerated wean pattern and adjust the weaning plan as necessary.

g.) An accelerated wean will be considered if the f/Vt ratio remains ≤ 70-80 at the end of each trial. The RT may accelerate the weaning by advancing the patient to the next step in the weaning chart for their last trial of the day.

h.) The RT will document the results of each day’s wean.
PROLONGED WEANING PROTOCOL (CON’T)

St. Mary’s Hospital in Kitchener, Ontario, Canada.

4. Phase IV - Documentation

a.) The Respiratory Therapist will chart all parameter changes with justification and patient response in the ventilator documentation screens and/or progress notes.

b.) The Respiratory Therapist will notify the bedside nurse of all changes in ventilatory support.

c.) Upon initiation of a difficult to wean plan, a difficult to wean care sheet must be started to plan and document the course of the patient’s weaning.

5. Phase V - Special Circumstances

a). PAV+ is contraindicated in air leak syndromes. Pressure support with an appropriate expiratory sensitivity (ensuring that the ventilator cycles to expiration at the appropriate time) may be utilized in this setting.

b). When using PAV+, the ventilator may not trigger appropriately in a patient with high intrinsic PEEP and air trapping. Great attention must be used to ensure that patient is able to appropriately trigger ventilator by optimizing triggering settings and compensating for the intrinsic PEEP.

PROTOCOL REFERENCES:

- General

- PAV

- Speaking Valves
  - Bach JR, Alba AS. I 990 Tracheostomy Ventilation, a study of efficacy with deflated cuffs and cuffless tubes. Chest 97:679- 683
REFERENCES


IMPORTANT: Please refer to the package insert for complete instructions, contraindications, warnings and precautions.

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