Hemodynamic Stability

Patients’ responses to both mechanical and spontaneous ventilation vary according to myocardial function and reserve capacity. Cardiac failure, which may not be apparent when a patient is receiving mechanical ventilation, can be exacerbated with transition to spontaneous ventilation. Signs of hemodynamic instability include an acute or gradual decrease in arterial blood pressure, tachycardia, bradycardia, dysrhythmias, weak peripheral pulses, decreased pulse pressure, acute or gradual increase in pulmonary capillary wedge pressure, decreased cardiac output, and decreased mixed venous oxygen saturation. Hemodynamic stability is difficult to evaluate when a patient is receiving vasoactive support, a common situation after cardiac surgery. Therefore, during weaning, hemodynamic parameters should be monitored closely in such patients.

Pulmonary Mechanics

For the purpose of assessing readiness to wean after cardiac surgery, 3 measurements of pulmonary mechanics typically are used: (1) minute volume, with its component parts of spontaneous tidal volume and respiratory rate; (2) vital capacity, expressed as milliliters per kilogram body weight; and (3) negative inspiratory pressure or force. Collectively, these measurements are used to evaluate the strength of respiratory muscles. Vital capacity of 15 mL/kg or higher and negative inspiratory pres-
sure of -30 cm H₂O or less are the most accurate predictors of a patient’s readiness to wean. Vital capacity depends on the effort exerted, and the patient should be coached to use maximal effort. Repeated measurements (eg, 3 measurements) are recommended to capture the patient’s best effort.

The findings of many clinical studies on pulmonary mechanics in a variety of patients in a variety of situations are conflicting so far as the value of measurements of pulmonary mechanics in predicting patients’ readiness to wean after short-term mechanical ventilation. In part, the conflicting findings can be explained by the failure to use standardized procedures to measure pulmonary mechanics across studies. Recommended standardized procedures for measurement of minute volume, vital capacity per kilogram, and negative inspiratory pressure are included in Tables 1 to 3.

**Adequacy of Gas Exchange**

Adequate ventilation within a desired range for the patient is a criterion of readiness to wean. Abnormal arterial carbon dioxide tension, chest-abdominal dyssynchrony, dyspnea, tachypnea, agitation, and unstable vital signs may indicate inadequate ventilation. Some of these signs may indicate that patients are “fighting” the ventilator; patients may have adequate ventilation with spontaneous breathing. Nursing judgment and a short, monitored trial of spontaneous ventilation or “bagging” can help differentiate the cause of distress.

Attention to the breathing pattern and the rate of mechanical ventilation is needed; abnormalities may signal problems with weaning. Signs of an inadequate breathing pattern, in addition to those listed previously, include shallow respiration, irregular respiration, intercostal retraction, suprasternal retraction, tracheal tug (upward and downward movement of the larynx with inspiration and expiration), respiratory alternans, and respiratory muscle paradox. An abnormal respiratory rate in any patient receiving mechanical ventilation should be evaluated with respect to the ventilator mode; however, a total respiratory rate (combined machine- and patient-initiated breaths) that exceeds 30/min

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**Table 1** Measurement of minute volume

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Wash hands and put on nonsterile gloves.</td>
</tr>
<tr>
<td>2.</td>
<td>Discontinue mechanical ventilation and allow up to 30 seconds for the patient to breathe spontaneously.</td>
</tr>
<tr>
<td></td>
<td>• If the patient becomes hypoxemic (decreased oxygen saturation as measured by pulse oximetry [SpO₂]), resume mechanical ventilation. Note in the patient’s record that mechanical ventilation was resumed and the SpO₂ value that prompted termination of pulmonary mechanics testing.</td>
</tr>
<tr>
<td></td>
<td>• If the patient tolerates the 30-second period without mechanical ventilation without a clinically significant decrease in SpO₂ and has spontaneous breaths, measure the expired volume per unit time.</td>
</tr>
<tr>
<td>3.</td>
<td>Explain to the patient that the purpose of this procedure is to test normal breathing.</td>
</tr>
<tr>
<td>4.</td>
<td>Attach adapter to endotracheal or tracheostomy tube and ask the patient to breathe normally.</td>
</tr>
<tr>
<td>5.</td>
<td>Turn the respirometer on. Simultaneously begin counting the number of respirations for exactly 60 seconds by the clock. Monitor heart rate, blood pressure, and SpO₂ as appropriate, during the procedure.</td>
</tr>
<tr>
<td>6.</td>
<td>Turn off the respirometer at the end of 1 minute. Disconnect the adapter and resume mechanical ventilation.</td>
</tr>
<tr>
<td>7.</td>
<td>Record the respiratory rate and total minute ventilation.</td>
</tr>
<tr>
<td>8.</td>
<td>Divide the respiratory rate into the total minute ventilation and record the resultant tidal volume.</td>
</tr>
</tbody>
</table>

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**Table 2** Measurement of vital capacity per kilogram

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Wash hands and put on nonsterile gloves.</td>
</tr>
<tr>
<td>2.</td>
<td>As appropriate, discontinue mechanical ventilation and allow up to 30 seconds for the patient to breathe spontaneously. If the patient becomes hypoxemic, as indicated by SpO₂ of 90% or less, resume mechanical ventilation.</td>
</tr>
<tr>
<td>3.</td>
<td>Explain to the patient that the purpose of this procedure is to test the maximum amount of air the patient can breathe out after the deepest breath possible.</td>
</tr>
<tr>
<td>4.</td>
<td>Attach adapter to endotracheal or tracheostomy tube and instruct the patient to breathe as deeply as possible.</td>
</tr>
<tr>
<td>5.</td>
<td>Turn on the respirometer. Instruct the patient to breathe out slowly and as completely as possible.</td>
</tr>
<tr>
<td>6.</td>
<td>Coach the patient to make the best possible effort (eg, “Come on, come on, breathe all the air out!”)</td>
</tr>
<tr>
<td>7.</td>
<td>Turn off the respirometer at the end of exhalation.</td>
</tr>
<tr>
<td>8.</td>
<td>Write down the value indicated for vital capacity.</td>
</tr>
<tr>
<td>9.</td>
<td>Repeat steps 4 through 8.</td>
</tr>
<tr>
<td>10.</td>
<td>Repeat steps 4 through 8.</td>
</tr>
<tr>
<td>11.</td>
<td>Disconnect adapter and resume mechanical ventilation.</td>
</tr>
<tr>
<td>12.</td>
<td>Record best effort (highest value) of the 3 measurements of vital capacity.</td>
</tr>
<tr>
<td>13.</td>
<td>Divide the best effort by the patient’s record.</td>
</tr>
<tr>
<td>14.</td>
<td>Record vital capacity per kilogram in the patient’s record.</td>
</tr>
</tbody>
</table>
may indicate that the patient is not ready to wean. Adequate oxygenation within a desired range for the patient receiving mechanical ventilation is a criterion of readiness to wean. Signs of inadequate oxygenation may include abnormal arterial oxygen tension, decreased mixed venous oxygen saturation, decreased saturation according to pulse oximetry, decreased PaO$_2$/fraction of inspired oxygen ratio, tachypnea, dyspnea, central cyanosis, restlessness, confusion, agitation, tachycardia, bradycardia, dysrhythmias, intercostal and suprasternal retraction, increasing or decreasing blood pressure, decreasing urine output, and metabolic acidosis. Poor oxygenation can be treated more easily in spontaneously breathing patients than can poor ventilation. Thus, oxygenation status while receiving mechanical ventilation is a relative indicator of readiness to wean.

**Capability for Spontaneous Ventilation**

Obviously, patients must be capable of spontaneous ventilation in order to wean. Spontaneous ventilation may be evidenced by any contribution of the patient to minute volume, such as the patient’s initiation of ventilator breaths, between or beyond the preset rate. Discontinuing mechanical ventilation, or setting the ventilator mode on flow by, and measuring spontaneous minute volume are often used to assess patients’ ability to breathe spontaneously.

**Level of Consciousness**

A reduced level of consciousness, including coma, is in and of itself not an indicator of inability to wean. Rather, changes in level of consciousness raise concerns about underlying instability of the patient’s condition from such covert causes as metabolic alterations, cerebral emboli, and residual anesthesia. Nonetheless, sustained alertness after surgery is one criterion for readiness to wean because it indicates reversal of anesthetic agents.

**References**

1. Goodnough-Hanneman SK. Ventilatory management. In: Boggs RL, Wooldridge-
**Update 2004**

Since the protocol for weaning from short-term mechanical ventilation was published in 1999, researchers have continued to search for effective weaning predictors. However, accurate and reproducible predictors of readiness to wean from mechanical ventilation remain elusive. Despite myriad studies, including a comprehensive and systematic evidence report of mechanical ventilation weaning from the Agency for Healthcare Research and Quality, clinicians do not have an effective method of assessing when a patient is ready to wean. The conclusion of the original practice protocol that weaning predictors perform inconsistently and with modest predictive power has been substantiated in more recent reviews.

Today, as in 1999, physiological stability and subjective adequacy of ventilation and oxygenation are the only assessments that have an adequate evidence base for patients who are receiving mechanical ventilation 3 or fewer days. Both research findings and expert consensus support daily screening trials and 2-hour T-piece trials for optimal weaning from mechanical ventilation.

On the basis of the evidence available to date, measurement of pulmonary mechanics, nutritional parameters, gas exchange, hemodynamics, and ventilatory capacity appear to offer little benefit, as independent predictors, to the prediction of readiness to wean. This does not mean that clinicians should abandon such measures; rather, the measures are used to form a clinical judgment of a given patient’s physiological status for assessment of readiness to wean.

The strongest predictor of readiness to wean in multiple populations across multiple settings appears to be the spontaneous breathing trial (SBT). The SBT is recommended for use as follows. A brief (ie, < 30 min) screening trial of SBT is used to assess the patient’s ability to progress to a formal trial of weaning. Thus, the screening trial serves as the predictor of readiness to wean. If the patient tolerates the screening trial, then a formal SBT trial (ie, up to 120 min) can commence. The patient should be monitored continuously for tolerance during both screening and formal SBT trials. Criteria to evaluate patient tolerance of a SBT include respiratory pattern, gas exchange, hemodynamics, and subjective comfort. The Table shows criteria that have been used in clinical trials to assess tolerance of SBT. Clinicians may find these criteria helpful as points of reference, but are cautioned to assess tolerance for each patient as compared with the patient’s status before the SBT.

The SBT is the most direct way to assess a patient’s ability to breathe without mechanical ventilatory support; however, a failed SBT may not be predictive of ventilator dependence. The clinical usefulness of the SBT rests with daily screening of readiness to wean from mechanical ventilation. After passing the screening test, the patient is then progressed to a formal SBT trial, for up to 2 hours, with continued monitoring of subjective and objective criteria.

**Bibliography**


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**Criteria used to assess patient tolerance of a spontaneous breathing trial**

**Gas exchange acceptability**
- SpO2 ≥ 85%
- PaO2 ≥ 50 mm Hg
- pH ≥ 7.32
- Increase in PaCO2 ≤ 10 mm Hg

**Hemodynamic stability**
- Heart rate <120 beats/min or change in heart rate ≤ 20%
- Systolic blood pressure <180 mm Hg or change ≤ 20%
- No vasopressors required

**Stable ventilatory pattern**
- Respiratory rate ≤ 30 breaths/min or change ≤ 50%
- No mental status changes (eg, somnolence, coma, agitation, anxiety)
- No diaphoresis
- No signs of increased work of breathing
Weaning From Short-term Mechanical Ventilation
Sandra K. Hanneman

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