ALERT
Premature attempts to wean or failure to recognize factors that negatively impact weaning may significantly compromise the child’s ability to have a positive outcome.

OVERVIEW
Children can be safely and efficiently weaned from positive-pressure ventilation (PPV) and then successfully extubated. One of several available weaning methods is chosen and individualized to meet a child’s needs. There are several phases of mechanical ventilation: initiation, maintenance, weaning, and extubation. A child may meet the criteria for weaning from PPV and wean successfully but still fail extubation because of other factors (Table 1).

<table>
<thead>
<tr>
<th>Table 1 Causes of Delayed or Unsuccessful Weaning</th>
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<tbody>
<tr>
<td><strong>Hypoxemia (or impaired oxygen delivery)</strong></td>
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<tr>
<td>Hypoventilation</td>
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<tr>
<td>Impaired pulmonary exchange</td>
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<tr>
<td>V/Q mismatching</td>
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<tr>
<td>Diffusion defect</td>
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<tr>
<td>Shunt</td>
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<tr>
<td>Increased work of breathing</td>
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<tr>
<td>Increased VO₂</td>
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<tr>
<td>Severe anemia</td>
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<tr>
<td>Decreased cardiac output</td>
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<tr>
<td>Fever</td>
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<td>Seizures</td>
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Ca²⁺, calcium; CNS, central nervous system; Mg²⁺, magnesium; VO₂, oxygen consumption; V/Q, ventilation/perfusion

Weaning involves the transition of the work of breathing and control of ventilation from the ventilator to the child. Identifying children who are candidates for weaning early by using screening assessments is important. The weaning process should begin after significant resolution or reversal of the pathologic condition for which it was initiated. The reason that the child was intubated (e.g., restrictive lung disease, lower airway disease, postoperative support, neuromuscular disease, and airway protection) influences the length of time required for weaning.

Before considering weaning, the assessment criteria (Box 1) should be met. Signs of weaning intolerance (Box 2) should be monitored. The respiratory therapist (RT) must understand how all these complex factors work together when adjusting ventilator settings.
Box 1 Assessment for Readiness to Wean

<table>
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<tr>
<td>Spontaneous tidal volume $\geq 5$ ml/kg</td>
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<tr>
<td>Fraction of inspired oxygen $\leq 0.4$</td>
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<td>Positive end-expiratory pressure $\leq 5$ cm H$_2$O</td>
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<tr>
<td>Peak inspiratory pressure $\leq 25$ cm H$_2$O</td>
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<tr>
<td>Vital capacity $&gt;15$ ml/kg</td>
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<tr>
<td>Negative inspiratory force $&gt;20$ cm H$_2$O</td>
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<tr>
<td>Arterial partial pressure of carbon dioxide (Paco$_2$) normal or at child’s baseline</td>
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<tr>
<td>pH: normal</td>
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<tr>
<td>Normal work of breathing</td>
</tr>
<tr>
<td>Hemodynamically stable</td>
</tr>
<tr>
<td>Adequate body strength and tone</td>
</tr>
<tr>
<td>Effective gag and cough reflexes</td>
</tr>
<tr>
<td>Pain control achieved without excessive sedation</td>
</tr>
<tr>
<td>Normal respiratory drive</td>
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<tr>
<td>Good aeration throughout lung fields</td>
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(Box 2 Weaning Intolerance Criteria

<table>
<thead>
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<tbody>
<tr>
<td>Respiratory rate $&gt;1.5$ to 2 times the child’s baseline (early)</td>
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<tr>
<td>Decreased respiratory rate (late)</td>
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<tr>
<td>Increased work of breathing evidenced by increased use of accessory muscles</td>
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<tr>
<td>Pale, gray, or cyanotic</td>
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<tr>
<td>General fatigue</td>
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Weaning by spontaneous breathing trials (using minimal pressure support) has been successful for some children. Tailoring the weaning method to the child and having a plan are important elements for successful weaning. At each step of the weaning process, the child must demonstrate the ability to sustain effective breathing. Primarily decreasing the ventilator rate decreases minute ventilation. Mean airway pressure is reduced with a decrease in continuous positive airway pressure (CPAP) or positive end-expiratory pressure (PEEP). Pressure support allows ventilatory muscle loads to be gradually restored during the weaning process because each breath is assisted. The duration of weaning can be minimized with strict adherence to a plan or protocol. If the spontaneous breathing trial is unsuccessful, an alternate method of weaning is selected. Examples of alternate weaning modes include:

- Weaning from pressure support ventilation (PSV)
- Synchronized intermittent mandatory ventilation/intermittent mandatory ventilation (SIMV/IMV)
- SIMV with pressure support
- Time-cycled, pressure-limited mode

When a child fails a spontaneous breathing trial or a weaning trial, the RT should:

- Return to the previous mode of ventilation.
Mechanical Ventilation: Weaning Pediatric Patients (Respiratory Therapy)

- Assess the reason for failure and institute measures to remedy the problem.
- Reassess readiness to wean.

Before beginning the weaning process, the RT should be aware that:
- Failed planned extubation rates vary from 2% to 20%, but only 50% of unplanned extubations are successful.\(^1\)
- Infants and children younger than 24 months who require mechanical ventilation for longer than 48 hours are at higher risk for extubation failure.\(^3\)
- Upper airway obstruction has been reported as the most common cause of extubation failure.\(^3\)
- Weaning is based on measurements of oxygenation and ventilations, including pulse oximetry, end-tidal carbon dioxide (ET\(\text{CO}_2\)) and transcutaneous carbon dioxide, and arterial blood gases (ABGs), as well as the child’s clinical appearance.
- A smaller endotracheal (ET) tube may impose a higher resistance to inspiration.

Required information about the child before weaning is attempted includes:
- His or her current ventilatory support and ventilator-influenced variables, including the type of flow delivery (continuous versus demand), the trigger sensor that initiates the breath, the pressure delivery, and the cycle variable that terminates the breath\(^1\)
- Whether child-ventilator asynchrony has occurred, especially in preterm infants with very short inspiratory times (less than 0.33 seconds)\(^1\)

EDUCATION
- Provide individualized, developmentally appropriate education to the family and child based on the desire for knowledge, readiness to learn, and overall neurologic and psychosocial state.
- Explain the reasons, purpose, and risks of weaning from mechanical ventilation.
- Discuss the possible sensations the child may experience during ventilator changes, including brief periods of shortness of breath.
- Reassure the child and family that weaning is done slowly, allowing breaks during the weaning process, especially for children who have been ventilated for long periods of time.
- Encourage questions and answer them as they arise.

ASSESSMENT AND PREPARATION
Child and Family Assessment
1. Perform hand hygiene before patient contact.
2. Introduce yourself to the child and family.
3. Verify the correct child using two identifiers.
4. Assess the child’s developmental level and ability to interact.
5. Assess the child’s and family’s understanding of the reasons for and the risks and benefits of the procedure.
6. Before beginning the weaning trial, reassess the child for readiness to wean.
7. Assess vital signs, including peripheral oxygen saturation (Sp\(\text{O}_2\)), ET\(\text{CO}_2\) or transcutaneous carbon dioxide level, and ABG values.
8. Assess the child’s level of fatigue, pain, and sedation, as well as his or her nutrition and fluid status.
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Rationale: Infants and small children respond to increased work of breathing by increasing the respiratory rate at the expense of tidal volume (VT) to maintain minute ventilation.

9. Assess for signs and symptoms that indicate hypercarbia, including sleepiness, hypertension, and dilated pupils.

Preparation
1. Review criteria for identifying weaning tolerance before initiating weaning.

   Rationale: A clear understanding of the weaning criteria is necessary to ensure early identification of weaning intolerance.

2. Ensure that a manual ventilation bag, mask, and suction are immediately available and connected at the child’s bedside.

PROCEDURE
Spontaneous Breathing Trials
1. Perform hand hygiene and don gloves.
2. Verify the correct child using two identifiers.
3. Explain the procedure to the child and family and ensure that they agree to treatment.
4. Ensure that the authorized practitioner minimizes sedation while providing adequate comfort measures.

   Rationale: The need for sedation for safety and comfort must be balanced to allow the child to breathe spontaneously. The minimum level of adequate analgesia supports successful weaning.

   **Adequate analgesia is possible without depressing respiratory effort and is not contraindicated in weaning or extubation.**

5. Define the duration and time intervals for spontaneous breathing, as well as the method for resting the child with baseline ventilator support between trials if needed.

   Rationale: The duration of a spontaneous trial is tailored to the individual child’s needs.

   a. During the trial, change the ventilator mode to CPAP based on weight, and pressure support based on the size of the ET tube.
   b. Alternatively, discontinue mechanical ventilation and allow the child to breathe through the ET tube connected to a T-piece. The T-piece method for weaning is generally reserved for the child with an adult-size ET tube. This method is typically not used with a smaller size ET tube because of excessive inspiratory resistance with smaller tubes.

   **When using the T-piece method, neither monitoring capability nor ventilation backup from the ventilator is available. Generally, a spontaneous breathing trial lasts 30 minutes to 2 hours.**

6. Observe for signs of weaning intolerance. Notify the authorized practitioner as indicated.
7. Once the trial is completed, assess the child for readiness to be extubated.
8. Remove gloves and perform hand hygiene.
9. Document the procedure in the child’s record.

**Synchronized Intermittent Mandatory Ventilation (SIMV)**
1. Perform hand hygiene and don gloves.
2. Verify the correct child using two identifiers.
3. Explain the procedure to the child and family and ensure that they agree to treatment.
4. Ensure that the authorized practitioner minimizes sedation while providing adequate comfort measures.

   **Rationale:** The need for sedation for safety and comfort must be balanced to allow the child to breathe spontaneously. The minimum level of adequate analgesia supports successful weaning.

   **Adequate analgesia is possible without depressing respiratory effort and is not contraindicated in weaning or extubation.**

5. Define the target IMV rate, incremental decreases in rate, and the frequency of changes.

   **Rationale:** The efficiency of weaning depends on a clear plan that may be subject to alterations due to special considerations. The IMV rate from which a child will be extubated is determined by his or her needs. In addition, the frequency of changes may be influenced by the duration of intubation.

6. Observe the type of flow delivery (continuous versus demand) and the sensor used to trigger the ventilator.

   **Rationale:** The child must be able to breathe through the circuit without experiencing an increase in effort. Flow sensors are generally more sensitive to effort than pressure. Unlike a circuit with continuous flow, the demand flow circuit requires the child to entrain a set amount of flow to open the valve, which requires greater strength.

7. Observe for signs of weaning intolerance. Notify the authorized practitioner, as indicated.

   **Infants and small children respond to increased work of breathing by increasing their respiratory rate at the expense of VT to maintain minute ventilation.**

8. Once the targeted rate is achieved, observe the child for positive indicators of successful extubation for 2 hours (or longer, as indicated) before the final evaluation of readiness to extubate.³

   **Rationale:** Intubations of less than 48 hours typically do not require a prolonged observation period;³ however, for children who have been intubated for a long duration, a longer observation period may be required.

9. Remove gloves and perform hand hygiene.
10. Document the procedure in the child’s record.

**Pressure Support Ventilation (PSV)**

1. Perform hand hygiene and don gloves.
2. Verify the correct child using two identifiers.
3. Explain the procedure to the child and family and ensure that they agree to treatment.
4. Ensure that the authorized practitioner minimizes sedation while providing adequate comfort measures.

   Rationale: The need for sedation for safety and comfort must be balanced to allow the child to breathe spontaneously. The minimum level of adequate analgesia supports successful weaning.

   **Adequate analgesia is possible without depressing respiratory effort and is not contraindicated in weaning or extubation.**

5. Define the target pressure support level and frequency of changes. The inspiratory pressure is initially set to achieve a desired $V_T$, and weaning occurs by gradual reduction of pressure.
6. Consider decreasing pressure support if the child maintains a $V_T$ that is within the goal range. In many cases, children are extubated from a low level of pressure support to offset the work of breathing imposed by the resistance of the ET tube. Some children require a slower wean in terms of timing of changes or decreases in pressure.

   Rationale: In many cases, weaning in this manner is used for children who have had prolonged periods of intubation and is known as sprinting the child for periods of time throughout the day.³

7. Observe for signs of weaning intolerance. Notify the authorized practitioner as indicated.

   Rationale: Recognition of a change in respiratory function directs further intervention and prevents complications. A rapid respiratory rate and decreasing $V_T$ may cause atelectasis.³

   **Infants and small children respond to increased work of breathing by increasing their respiratory rate at the expense of $V_T$ to maintain minute ventilation.**

8. Continue to wean the child until the target pressure support level has been achieved.

   Rationale: Weaning the child to minimal but adequate support before extubation may promote success.

   **Although target PSV goals have been suggested, the final target and duration of spontaneous breathing must be individualized. In some cases, however, prolonging a spontaneous trial may impose greater work of breathing, tiring the child.**

9. Once the targeted pressure support has been achieved, observe the child for positive
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indicators of successful extubation for 2 hours (or longer, as indicated) before final evaluation of readiness to be extubated. Rationale: Children who have been intubated for a short time typically do not require a prolonged observation period. However, children who have been intubated for a long time may require a longer observation period.

10. Remove gloves and perform hand hygiene.
11. Document the procedure in the child’s record.

Pressure Support Ventilation/Spontaneous Intermittent Mandatory Ventilation (PSV/SIMV)

1. Perform hand hygiene and don gloves.
2. Verify the correct child using two identifiers.
3. Explain the procedure to the child and family and ensure that they agree to treatment.
4. Ensure that the authorized practitioner minimizes sedation while providing adequate comfort measures.

Rationale: The need for sedation for safety and comfort must be balanced to allow the child to breathe spontaneously. The minimum level of adequate analgesia supports successful weaning.

Adequate analgesia is possible without depressing respiratory effort and is not contraindicated in weaning or extubation.

5. Choose one of these options:

Rationale: Weaning strategy varies depending on the size of the child and the duration of intubation.

Option 1
1. Decrease the IMV to a targeted rate with the PSV level continually adjusted to achieve the desired VT. For infants, a ventilator capable of volume ventilation with small VT, continuous flow, and a flow sensor at the child interface minimizes the work of breathing during weaning.

Rationale: As IMV is decreased, pressure support may be adjusted to reduce the work of breathing and support further weaning of the child from IMV.

2. Wean the child from PSV.
   a. Consider an initial decrease in PSV in small increments every few hours.
   b. Continue to wean the child until the targeted pressure support level has been achieved.

Rationale: Weaning the child to minimal but adequate support before extubation promotes success.

Although target PSV goals have been suggested, the final target and duration of spontaneous breathing must be individualized. In some
cases, however, prolonging a spontaneous trial may impose greater work of breathing, tiring the child.

c. Observe for signs of weaning intolerance. Notify the authorized practitioner, as indicated.

Rationale: Recognition of a change in respiratory function directs further intervention and helps prevent complications. A rapid respiratory rate and $V_T$ less than 5 ml/kg may cause atelectasis.

Infants and small children respond to increased work of breathing by increasing their respiratory rate at the expense of $V_T$ to maintain minute ventilation.

d. Observe the child for positive indicators of successful extubation for 2 hours (or longer, as indicated) before the final evaluation of readiness to extubate.

Rationale: Children who have been intubated for a short time typically do not require a prolonged observation period. However, children who have been intubated for a long time may require a longer observation period.

3. Remove gloves and perform hand hygiene.
4. Document the procedure in the child’s record.

Option 2
1. Decrease SIMV and PSV with each step for a predefined frequency and duration of changes.

Newer ventilators incorporate modes that allow variable pressure support with a preset SIMV rate. With these ventilators, SIMV is actively decreased while the pressure support is automatically adjusted to guarantee a $V_T$ of approximately 4 to 6 ml/kg.

2. Once the targeted settings are obtained, observe the child for indicators of successful extubation for 2 hours (or longer, as indicated) before the final evaluation of readiness to extubate.

Rationale: Children who have been intubated for a short time typically do not require a prolonged observation period. However, children who have been intubated for a long time may require a longer observation period.

3. Remove gloves and perform hand hygiene.
4. Document the procedure in the child’s record.

Time-Cycled, Pressure-Limited Mode
1. Perform hand hygiene and don gloves.
2. Verify the correct child using two identifiers.
3. Explain the procedure to the child and family and ensure that they agree to treatment.
4. Ensure that the authorized practitioner minimizes sedation while providing adequate comfort measures.
Rationale: The need for sedation for safety and comfort must be balanced to allow the child to breathe spontaneously. The minimum level of adequate analgesia supports successful weaning.

Adequate analgesia is possible without depressing respiratory effort and is not contraindicated in weaning or extubation.

5. Determine the setting for extubation before initiating the weaning process.

While the guidelines to wean are listed in a stepwise fashion, changes in fraction of inspired oxygen (FIO₂), peak inspiratory pressure (PIP), IMV rate, PEEP, and pressure support are made in an alternating fashion in many cases, based on clinical status and measurement parameters.

6. Decrease the FIO₂. If the circuit provides continuous flow, the child can breathe spontaneously between breaths to ensure that the minute ventilation requirement is being met.

Rationale: High FIO₂ increases the risk of lung toxicity.

If PSV is not available, the spontaneous breaths may be shallow, which puts the child at risk for atelectasis.

If the child has been in the assist-control mode (rather than SIMV), switching to SIMV first to allow spontaneous breathing may improve the success of weaning.

7. Decrease PIP by 1- to 2-cm H₂O increments until arterial partial pressure of carbon dioxide (PaCO₂) reaches predetermined levels or until the predetermined level of PIP is achieved.

Do not continue to decrease PIP if Vt is less than 5 ml/kg.

8. Decrease PEEP in 1-cm H₂O increments to predetermined levels, ensuring a partial pressure of arterial oxygen (PaO₂) of more than 80 mm Hg. Consider concurrent decreasing of PEEP with PIP to facilitate maintenance of VT per minute ventilation without burdening the child.

Rationale: Decreasing PEEP independently or concurrently with PIP allows VT to remain unchanged while facilitating decreased PIP.

Mean airway pressure will also drop; monitor the child’s PaO₂ closely.

9. Decrease the IMV rate, generally in increments of one or two breaths per minute.

Rationale: When the target PIP and PEEP have been achieved with acceptable VT per minute ventilation, the child can be weaned from the IMV rate.
10. Once the targeted settings are obtained, observe the child for positive indicators of successful extubation for 2 hours (or longer, as indicated) before the final evaluation of readiness to extubate.\(^1\)

Rationale: Intubations of less than 48 hours typically do not require a prolonged observation period;\(^3\) however, for children who have been intubated for a long duration, a longer observation period may be required.

11. Remove gloves and perform hand hygiene.
12. Document the procedure in the child’s record.

**MONITORING AND CARE**

1. Ensure adequate cardiopulmonary monitoring: clinical assessments and observations, blood pressure level, respiratory rate, SpO\(_2\), and ET\(\text{CO}_2\) level.

Rationale: Cardiopulmonary monitoring allows assessment of weaning tolerance and allows the authorized practitioner to immediately respond to the child’s physiologic status.

2. Evaluate the child’s clinical stability, including the factors that identify readiness to wean, before and during the weaning process.

Rationale: Premature attempts to wean or failure to recognize interfering factors may significantly compromise the child.

3. Ensure that a manual ventilation bag, mask, and suction remain immediately available and connected at the child’s bedside.

4. Continuously observe and monitor the child, including vital signs, \(V_t\), ABGs, SpO\(_2\), ET\(\text{CO}_2\) or transcutaneous carbon dioxide, and signs of increased work of breathing.

Rationale: Children exhibit more subtle clinical signs of fatigue than adults. Regardless of strategy, vigilance is important in monitoring fatigue. Increased work of breathing leading to fatigue may occur in a short time frame with decompensation occurring abruptly.

5. Elevate the head of the bed as the child’s condition permits to allow the diaphragm to drop, facilitating excursion.

Rationale: The principal muscle that supports respiration in infants and young children is the diaphragm. Any factor that impedes diaphragm excursion compromises the child.

6. Assess the child’s nutritional status and consult with the authorized practitioner as needed.

Rationale: Consideration must be given to the potential increases in energy expenditure.
7. Observe the child for signs or symptoms of pain. If pain is suspected, report it to the authorized practitioner.

EXPECTED OUTCOMES
- Efficient and successful weaning
- Adequate oxygenation and ventilation
- No injury to child
- Hemodynamic stability
- Acceptable level of comfort

UNEXPECTED OUTCOMES
- Delay of further weaning due to fatigue
- Hypercapnia or hypoxemia
- Atelectasis
- Tracheal injury
- Hemodynamic instability
- Unmanaged pain and agitation
- Retinopathy of prematurity because of oxygen toxicity

DOCUMENTATION
- Cardiopulmonary assessment, including vital signs, lung sounds, work of breathing, ABGs, SpO2, and ETco2 or transcutaneous carbon dioxide monitoring
- Ventilator settings as weaning progresses, including FiO2, mode, VT, IMV rate, PIP, and PEEP per the organization’s practice
- Signs of weaning intolerance
- Unexpected outcomes and related interventions
- Additional interventions and the child’s response
- Comfort assessment and any specific interventions provided
- Child and family education

REFERENCES

ADDITIONAL READINGS
Mechanical Ventilation: Weaning Pediatric Patients (Respiratory Therapy)

*In these skills, a “classic” reference is a widely cited, standard work of established excellence that significantly affects current practice and may also represent the foundational research for practice.

Elsevier Skills Levels of Evidence
- Level I - Systematic review of all relevant randomized controlled trials
- Level II - At least one well-designed randomized controlled trial
- Level III - Well-designed controlled trials without randomization
- Level IV - Well-designed case-controlled or cohort studies
- Level V - Descriptive or qualitative studies
- Level VI - Single descriptive or qualitative study
- Level VII - Authority opinion or expert committee reports

Supplies
- Gloves
- Intubation equipment and supplies
- Manual ventilation bag and mask and second oxygen source
- Pulse oximeter
- Suctioning equipment
- Tracheotomy collar or T-piece adapters
- Weaning protocol or documented plan

Clinical Review: Rhonda Bevis, Ed.D, MS, RRT

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