

Mechanical Ventilation: Pediatric Pressure Mode (Respiratory Therapy)

ALERT

Use appropriate ventilator settings to overcome the challenges of ventilating children and provide optimal oxygenation and ventilation and minimize the potential harmful effects of positive pressure in smaller lungs.

OVERVIEW

Conventional modes of mechanical ventilation provide positive pressure ventilation (PPV) in an attempt to improve oxygenation and ventilation, prevent cardiovascular failure, manage intracranial pressure, protect the airways, and improve oxygen delivery to the tissues. PPV can be used on a short-term basis as a temporary mode of support until the child's condition no longer warrants it or as long-term therapy in children with chronic conditions requiring mechanical ventilation. PPV can be either pressure mode or volume mode.

Positive pressure ventilators raise the mean airway pressure above intrapleural pressure, thus reversing the intrathoracic pressure dynamics from spontaneous breathing. Normal glottis closure at end-exhalation is prevented when an artificial airway is present; therefore, a minimal amount of positive end-expiratory pressure (PEEP) (approximately 5 cm) maintains physiologic functional residual capacity (FRC), which is the amount of air left in the lungs at end-expiration in children.¹ In children with pulmonary disease, PEEP is adjusted according to underlying pathophysiology. One goal for the use of PEEP is to reduce the fraction of inspired oxygen (FIO₂).

Common modes of ventilation:

- Pressure-regulated ventilation delivers a breath with a preset pressure for a specific length of time.
- In the assist-control (A/C) mode, the volume or pressure and the inspiration and expiration durations are set, which determines the ventilator rate. This mode allows triggering by the child; in response, the machine delivers a tidal volume (V_T) approximating the mandatory breath. If the child fails to trigger, the ventilator automatically delivers the preset volume or pressure.
- Dual-control ventilation, which is becoming more widely available, allows both V_T and peak inspiratory pressure (PIP) ventilation simultaneously with time-cycling to terminate inspiration.

It is important to understand how and when to make ventilator adjustments to improve oxygenation and ventilation. An important aspect of caring for a child on PPV is the use of lung protective strategies, which include V_T for age and body weight (5 to 8 ml/kg), controlled plateau pressure of 28 mm Hg or less, and moderate levels of PEEP.²

PEEP is based on the child's disease process. For children undergoing ventilation for general physiologic support, a minimum PEEP of 5 mm Hg is considered adequate to replicate FRC.¹ For children with pulmonary disease, the PEEP is adjusted according to the underlying pathophysiology. At high levels of PEEP, which increase mean airway pressure, the V_T can be reduced for lung protection in many cases.

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.

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- Explain the therapy and equipment to the child and family, including the reasons for and the purpose and risks of PPV therapy, and provide an explanation of the equipment alarms.
- Discuss sensory information, including the sounds of the ventilator and alarms, the sensation of lung inflation, and coughing.
- Explain that medications, including local anesthetics, sedatives, and pain medications will be used to minimize the child's pain and anxiety during the procedure.
- Discuss relaxation methods that can be incorporated into the child's care, including reading to him or her, providing quiet distractions, and facilitating rest.
- Identify a method of communication between the child and family and the health care professionals.
- Provide assurance that the family can be present and involved in the child's care.
- Discuss the need for suctioning of the artificial airway at regular intervals and the expected coughing sensation.
- 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. If able, assess the child's developmental level and ability to interact.
5. Determine the family's desire to be present during the procedure.
6. Assess the family's understanding of the reasons for and the risks and benefits of the procedure.
7. Assess the child's vital signs.
8. Assess the child for signs and symptoms of ventilatory failure, including increased arterial partial pressure of carbon dioxide (P_{aCO_2}) and symptoms of hypercarbia, such as acidosis, decreased mental status, tachycardia, hypertension, and dilated pupils.
9. Assess the child for signs and symptoms of hypoxemia, including decreased arterial oxygen saturation, pale or cyanotic color, tachycardia or bradycardia, tachypnea, agitation, or decreased mental status, and increased work of breathing (retractions).
10. Assess the child's cardiovascular stability.

Preparation

1. Ensure that a manual resuscitation bag with mask and suction equipment are immediately available and assembled at the child's bedside.
2. Obtain the child's weight in kilograms.

PROCEDURE

1. Perform hand hygiene.
2. Explain the therapy to the family and ensure that they agree to treatment.
3. Ensure that a cardiopulmonary monitor is in place to measure end-tidal carbon dioxide ($ETCO_2$) levels and oxygen saturation levels, if indicated.
4. Select the mode of ventilation.
 - a. The PIP-to-PEEP ratio is proportionate to V_T ; therefore, changes in the PIP-to-PEEP ratio will cause proportional changes in V_T .

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- b. For pressure-controlled/limited mode, A/C or synchronized intermittent mandatory ventilation (SIMV) is the most commonly used mode.
- c. Pressure-controlled ventilation regulates pressure during each cycle but does so without a preset VT.

Rationale: Pressure-controlled ventilation is selected for children who require a ventilation strategy focused on maintaining an exact PIP-to-PEEP ratio.

- 5. Adjust the PIP and PEEP to achieve the targeted VT.
 - a. The initial settings may be arbitrary.
 - b. One method is to set the desired PEEP and then adjust the PIP upward until the desired VT is achieved.

Rationale: Parameters are based on previous ventilator settings or the respiratory therapist's (RT's) best estimate.

- 6. Set the cycle mechanism.

Rationale: The cycle mechanism determines the termination of inspiration with a preset inspiratory time, VT, or flow.

- 7. Set the rate, trigger, inspiratory-to-expiratory (I:E) ratio, and PEEP.
 - a. These settings must be individualized to the child and disease state.
 - b. Monitor the mean airway pressure and minute volume closely as the rate and I:E ratio are adjusted.
- 8. For pressure-regulated volume control (PRVC), set a targeted VT and an appropriate I:E ratio.
 - a. In most cases, the PRVC is time cycled.
 - b. The VT is established by the ventilator measuring resistance and compliance and is controlled with variable flow ($VT = \text{inspiratory time} \times \text{flow}$).
 - c. Many ventilators with these modes have a five-breath "learning curve" to adjust to the child's resistance and compliance. Occasionally, the child may struggle during those five breaths, especially at lower rates.
 - d. If the high-pressure limit alarm sounds, the child may need suctioning or may have progressive lung disease with decreasing compliance.

Rationale: The goal is to set the ventilator to deliver the target VT with the least amount of pressure, which may be preset or variable (with a high-pressure limit). The child's size and condition guide the I:E ratio.

- 9. Set and activate the low-pressure and high-pressure alarms.

Rationale: Alarm settings are based on the cycling mechanism chosen. Low-pressure alarms are used to detect disconnections in the system. High-pressure alarms are used for notification of increased pressure in the system.

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10. Discard supplies and perform hand hygiene.
11. Document the procedure in the child's record.

MONITORING AND CARE

1. Monitor the child's cardiopulmonary status, including vital signs and indicators of oxygenation and ventilation.
2. Monitor the child's physiologic stability, including cardiac function and hemodynamic changes (heart sounds, heart rate, blood pressure, and perfusion).

Rationale: Increased intrathoracic positive pressure may reduce venous return and cardiac output. Likewise, positive pressure may cause a pneumothorax, which may also decrease cardiac output.

3. Observe for child-ventilator synchrony.

Rationale: Asynchrony causes increased work of breathing and distress. Asynchrony in a small child is commonly associated with flow regulation; access to flow and speed of delivery influence the child's ability to breathe comfortably.

4. Perform a ventilator check including FI_{O_2} , PIP, VT, PEEP, mean airway pressure, and other relevant settings, such as the temperature of the inspired gas.

Rationale: Changes in oxygen flow may occur from the oxygen source; auto-PEEP may also occur. Body temperature can be significantly altered by the temperature of inspired gas.

5. Confirm the activation of all alarms during each shift.

Rationale: Alarms help ensure that the child is safe.

6. Provide additional ventilatory support, including manual breaths and adjustments in mechanical ventilation as indicated by signs of hypoxemia, hypercarbia, and hemodynamic instability. Provide manual ventilation with a manual resuscitation bag, if needed because of deterioration.

Rationale: Early intervention when inadequate ventilator support and hemodynamic instability occur may prevent further clinical deterioration.

7. Monitor and adjust the ventilator's settings according to treatment strategies.

Rationale: Changes in lung compliance may change the PIP or VT.

8. Monitor the ventilator alarms and watch for changes from prescribed settings, including an increased PIP or a change in VT.

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Rationale: An alarm indicating an increased PIP or change in VT may be associated with a need for suctioning or an airway obstruction. A low-pressure alarm may indicate that the ventilator tubing has been disconnected.

9. Ensure that the child's artificial airway is secure and stabilized.
 - a. Consider attaching the circuit to the bed or device. Avoid the use of a cumbersome connecting apparatus.

Rationale: Attaching the circuit to the bed or device eliminates undue pressure on the skin from the artificial airway and tubing.

- b. Resecure the tape whenever it loosens. Use fresh tape and fresh skin barrier materials with each change of tape.
 - c. Use a commercial artificial airway tube holder.
10. Suction the child's artificial airway as indicated and observe the characteristics of secretions.

Rationale: Suctioning the artificial airway maintains airway patency and removes secretions.

11. Encourage daily drug holidays (also referred to as sedation vacations) and check paralytic status if the child is undergoing paralytic therapy.³

Rationale: Sedation and neuromuscular blockade may be necessary to achieve ventilator synchrony, but paralytics mask the child's underlying neurologic state. Daily sedation interruption improves outcomes in children and significantly reduces the duration of mechanical ventilation and intensive care.

12. Observe the child for signs and symptoms of pain. If pain is suspected, report it to the authorized practitioner

EXPECTED OUTCOMES

- Adequate oxygenation and ventilation
- Maintenance of adequate pH and PaCO₂
- Decreased work of breathing
- Ventilation without lung injury
- Hemodynamic stability
- Maintenance of skin integrity
- Airway in correct position
- No infection
- Mobilization and removal of secretions
- Adequate airway humidification
- Adequate pain control during the procedure

UNEXPECTED OUTCOMES

- Inadequate ventilation and oxygenation (hypoxemia, hypercarbia, acidosis, alkalosis)

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- Lung overinflation, air-leak syndrome (pneumothorax, pneumomediastinum, pneumoperitoneum, pneumopericardium, subcutaneous emphysema)
- Acute respiratory distress syndrome
- Ventilator-induced lung injury (volutrauma, atelectrauma, biotrauma)
- Hemodynamic instability
- Facial pressure injury
- Malpositioned artificial airway
- Unplanned extubation or decannulation
- VAP
- Tenacious sputum
- Artificial airway obstruction
- Inadequately managed pain or anxiety
- Child-ventilator dyssynchrony

DOCUMENTATION

- Cardiopulmonary assessment, including vital signs, lung sounds, work of breathing, and arterial blood gas, pulse oximetry, and ET_{CO}₂ monitoring values
- Date and time of initiation of ventilator assistance
- Record of ventilator settings, including FIO₂, mode, VT, PIP, rate, and PEEP
- Timing of suctioning and characteristics of respiratory secretions
- Pain assessment and specific interventions provided
- Child's response to the procedure
- Family education
- Unexpected outcomes and related interventions

REFERENCES

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3. Vet, N.J. and others. (2014). Daily interruption of sedation in critically ill children: Study protocol for a randomized controlled trial. *Trials*, 15, 55. doi:10.1186/1745-6215-15-55 ([Level II](#))

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- 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

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Supplies

- Manual resuscitation bag with mask
- Air source
- Oxygen source
- Conventional mechanical ventilator
- Cardiopulmonary monitor
- Capnograph
- Pulse oximeter
- Suction source with canister, tubing, and catheters

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