Mechanical Ventilation: Neonate (Respiratory Therapy)

ALERT

Mechanical ventilation can be associated with acute or chronic respiratory tract injury, such as atelectrauma, volutrauma, barotrauma, oxygen toxicity, and a pulmonary or systemic inflammatory response to lung trauma.

Avoid an irregular respiratory pattern by using patient-triggered or synchronized ventilation.[1] Irregular respiratory patterns in neonates can lead to asynchrony with the ventilator, resulting in high airway pressure, poor oxygenation, and fluctuation in intracranial pressure when the ventilator breath occurs just after the neonate exhales.

OVERVIEW

Mechanical ventilation is most commonly required for the extremely low-birth-weight or critically ill neonate. The goals of mechanical ventilation are to facilitate adequate gas exchange, minimize the risk of lung injury, decrease the neonate's work of breathing (WOB), and optimize the neonate's comfort.

There are several basic conventional modes of mechanical ventilation for neonates: synchronized intermittent mandatory ventilation, assist-control ventilation, and pressure-support ventilation. Recently, two new modes of ventilation have become available for the neonate population: volume-targeted ventilation and neurally adjusted ventilator assist (NAVA). Volume-targeted ventilation provides a continuous flow of gas throughout inspiration, producing the characteristic "square wave" of flow versus time. Peak pressure and volume delivery occur at the end of inspiration, resulting in slower and more uniform lung inflation. The pressure is varied to deliver the desired volume of gas. NAVA is a mode of ventilation designed to improve patient-ventilator interaction by interpreting a neural signal from the diaphragm to trigger a supported breath. Neurally triggered breaths may reduce trigger delay, ventilator response times, and WOB. These various modes of mechanical ventilation are best classified on the basis of three factors: how each breath is initiated, gas flow during the ventilator breath, and how the breath ends (Table 1).

Table 1 Classification of Basic Modes of Ventilation

Factors	Definition
How is each breath initiated?	Controlled ventilation: Breath is initiated by a timing mechanism unrelated to the neonate's own inspiratory effort. Synchronized or patient-triggered: The breath is triggered by the neonate's inspiratory effort.
How is gas flow controlled?	Pressure-controlled: A predetermined pressure is delivered. Volume-controlled: A predetermined tidal volume is delivered.
How is each breath ended?	Time-cycled: The breath is terminated based on predetermined elapsed time. Volume-cycled: The breath is terminated based on cessation of inspiratory flow.

(Data from Kacmarek, R.M., Stoller, J.K., Heuer, A.J. [Eds.]. [2017]. *Egan's fundamentals of respiratory care* [11th ed.]. St. Louis: Elsevier.)

In addition to the basic conventional modes of mechanical ventilation, there are other high-frequency ventilation (HFV) modes: high-frequency oscillatory ventilation (HFOV) and high-frequency jet ventilation (HFJV). HFV uses small tidal volumes (V_Ts) and delivers high rates.

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Mechanical Ventilation: Neonate (Respiratory Therapy)

HFOV's advantage over conventional mechanical ventilation is the ability to deliver sub-tidal volume breaths at high frequencies. Indications for using HFOV include severe lung disease that is unresponsive to conventional ventilation, pulmonary air leaks, and pulmonary hypoplasia. HFJV is most effective with disorders in which the major problem is carbon dioxide elimination because it can be achieved more readily at a lower peak and mean airway pressure than with HFOV. Severe atelectatic disorders, such as respiratory distress syndrome, and obstructive disorders, such as meconium aspiration syndrome, have been shown to respond to HFJV. The appropriate ventilator mode to be used is based on the individual neonate's clinical condition, disease process, and response to previous ventilatory support (Table 2).

Table 2 Modes of Mechanical Ventilation	
Modes of Ventilation	**Definition**
Conventional ventilation	
IMV	A set number of breaths are delivered at a predetermined rate, regardless of where the neonate is in the respiratory cycle.
PTV, SIMV	A set number of breaths are delivered and synchronized with neonate's breath. If a breath is not sensed, the ventilator will deliver a breath at the end of a set time interval. A set PIP and PEEP are delivered.
PTV, AC ventilation	A time-cycled, pressure-limited breath is delivered with every spontaneous breath. Each spontaneous breath is supported with set PIP and PEEP. A background rate is set in the event of apnea.
PTV, PS ventilation	Spontaneous breaths are supported by a preset PS setting. Similar to AC, but breath is terminated when neonate's inspiratory flow declines to a preset threshold. PIP delivered may vary between breaths and is measured above PEEP baseline.
PTV, pressure-control ventilation	Similar to SIMV or AC, but set pressure is measured above baseline PEEP. Flow is delivered per the neonate's demand.
PS, volume-guaranteed	Ventilator provides a set tidal volume responsive to changes in neonate compliance. PIP may vary with each breath based on neonate's tidal volume.
High-frequency ventilation: A form of mechanical ventilation that uses small tidal volumes at rates of at least 180 breaths/min to ventilate neonates.	
High-frequency jet ventilation	Short, rapid, high-velocity pulses that are delivered directly. Indications for use are mainly for disorders in which carbon dioxide elimination is the major problem.
High-frequency oscillatory ventilation	A small volume of vibrating gas is moved toward and then away from the neonate. The amount of gas moved is referred to as amplitude, with the resulting push-pull eliminating carbon dioxide buildup and delivering oxygen.

AC, assist control; IMV, intermittent mandatory ventilation; PEEP, peak end-expiratory pressure; PIP, peak inspiratory pressure; PS, pressure support; PTV, patient-triggered ventilation; SIMV, synchronized intermittent mandatory ventilation
(Data from Kacmarek, R.M., Stoller, J.K., Heuer, A.J. [Eds.]. [2017]. *Egan's fundamentals of respiratory care* [11th ed.]. St. Louis: Elsevier.)

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Mechanical Ventilation: Neonate (Respiratory Therapy)

EDUCATION

- Provide individual education that is developmentally and culturally appropriate based on the family's desire for knowledge, readiness to learn, and psychosocial state.
- Explain the purpose for and complications of mechanical ventilation.
- Provide descriptions and explanations of the equipment and alarms.
- Discuss the need for suctioning and explain the procedure to the family.
- Discuss methods the family may use to interact with and calm the neonate.
- Encourage questions and answer them as they arise.

ASSESSMENT AND PREPARATION

Assessment

1. Perform hand hygiene before patient contact.
2. Introduce yourself to the family, if they are present at the bedside.
3. Verify the correct neonate using two identifiers.
4. Determine the family's desire to be present during the procedure.
5. Assess the family's understanding of the reasons for and the risks and benefits of the procedure.
6. Inspect ventilator equipment and settings.

a. Review these parameters when using conventional ventilation: fraction of inspired oxygen (F_{IO_2}), ventilator rate, positive inspiratory pressure (PIP), positive end-expiratory pressure (PEEP), V_T, inspiration-to-expiration ratio, flow rate, and mean airway pressure (MAP) (Table 3).
b. Review these parameters when using HFV: F_{IO_2}, amplitude, frequency, and MAP (Table 3).

Table 3 Definitions Associated with Ventilation	
Amplitude	Change in pressure generated across the MAP and measured within the circuit. Setting used in high-frequency ventilation. Mainly used to control carbon dioxide levels.
Frequency	Mechanical rate measured in Hz: 1 Hz = 60 breaths/min. Setting used in high-frequency ventilation.
Functional residual capacity	The volume of gas that remains in the lungs after normal expiration.
Inspiratory—expiratory ratio	The ratio of time spent in inspiration to time spent in expiration.
Mean airway pressure (MAP)	The average pressure delivered to the airways throughout an entire respiratory cycle. MAP is dependent on ventilator rate, gas flow through the ventilator circuit, PIP, PEEP, and inspiratory time. MAP affects atelectasis, intrapulmonary shunting, and oxygenation.
Mechanical dead space	Gas that fills the ventilator circuit for availability in inspiration, as well as exhaled gas. Minimal dead space is desired. Excessive dead space can cause increased retention of carbon dioxide.
Positive end-expiratory pressure (PEEP)	The amount of constant pressure remaining at end of expiration. PEEP helps to maintain functional residual capacity to prevent atelectasis. PEEP has an effect on oxygenation, but it can lead to an increase in arterial partial pressure of carbon dioxide.

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Mechanical Ventilation: Neonate (Respiratory Therapy)

Peak inspiratory pressure (PIP)	The amount of pressure used during inspiration. PIP has an effect on both oxygenation and ventilation.
Physiologic dead space	Anatomic plus alveolar dead space: • Anatomic dead space is the volume of gas within the area of the pulmonary conduction airways that cannot engage in gas exchange. • Alveolar dead space is the volume of inspired gas that reaches the alveoli but does not participate in gas exchange because of inadequate perfusion to those alveoli.
Tidal volume	The amount of air that moves into or out of the lungs with each breath at rest.
Total lung capacity	The amount of air contained in the lung after a maximal inspiration.
Vital capacity	The volume of air maximally inspired and maximally expired.

MAP, mean airway pressure; PEEP, peak end-expiratory pressure; PIP, peak inspiratory pressure
(Data from Kacmarek, R.M., Stoller, J.K., Heuer, A.J. [Eds.]. [2017]. *Egan's fundamentals of respiratory care* [11th ed.]. St. Louis: Elsevier.)

7. Assess ventilator alarm status.

If the alarm continues to sound inappropriately despite interventions, report it to the authorized practitioner.

Preparation

1. Ensure that an appropriate-size manual ventilation bag or manual resuscitator, mask, and suction are immediately available and connected at the neonate's bedside.
2. Ensure that the head of the bed is elevated, unless contraindicated.

Rationale: Elevating the head of the bed reduces the incidence of aspiration, is a recommended practice in the prevention of ventilator-associated pneumonia, and is the preferred position to decrease the risk of intraventricular hemorrhage.

PROCEDURE

1. Perform hand hygiene and don gloves.
2. Verify the correct neonate using two identifiers.
3. Explain the procedure to the family (if they are present at the bedside) and ensure that they agree to treatment.
4. Ensure that the authorized practitioner provides the appropriate sedation and pain medications.

Rationale: Early assessment of and intervention for the neonate's comfort allows immediate attention to any problems. Sedation may be necessary to achieve ventilator synchrony.

5. Evaluate the neonate's vital signs and cardiopulmonary stability, including spontaneous respiratory rate, chest expansion or vibration, and response to mechanical ventilator rates.

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Mechanical Ventilation: Neonate (Respiratory Therapy)

6. Auscultate the neonate's breath sounds, including upper and lower lung fields and differences in left and right lung fields, to evaluate for the equality of aeration and the presence of adventitious breath sounds.
7. Observe the chest wall vibration when HFV is in use.

    Rationale: Volume and tone of HFV breath sounds affect the ability to auscultate heart sounds.

8. Place the ventilator on standby to assess heart sounds, and manually ventilate the neonate to assess normal breath sounds.

    Rationale: Chest wall vibration is an indicator of lung compliance, airway patency, and effectiveness of ventilator settings. A sudden decrease in chest wall vibration may indicate a plugged endotracheal (ET) tube or a pneumothorax.

9. Examine the neonate for signs and symptoms of ventilatory failure, including increased arterial partial pressure of carbon dioxide ($PaCO_2$) with decreasing pH, increased WOB, tachypnea, and increased retractions.
10. Examine the neonate for signs and symptoms of hypoxemia, including decreased oxygen saturation, pale or cyanotic color, tachycardia or bradycardia, tachypnea, agitation, increased WOB, increased retractions, and acidosis.
11. Review radiographic findings, arterial blood gas analysis (ABG), and the neonate's clinical status for indications that ventilator weaning can be initiated.
12. Evaluate the need for suctioning.
13. Adjust ventilator settings as ordered on the basis of treatment strategies and the neonate's response in collaboration with the authorized practitioner.

    Rationale: Changes in lung compliance may occur, resulting in the need for more or less ventilator support.

    Keep in mind that the goal is to wean the neonate from the ventilator as soon as possible to minimize lung injury.

14. Suction the ET tube using the shallow or measured technique, preferably with an inline suction device.

a. Suction as needed, not on a routine schedule.

    Rationale: Suctioning is not a benign procedure; therefore, it should be done only as needed to maintain airway patency and remove secretions.

b. Observe and document the characteristics of secretions.

    Rationale: Careful assessment of the neonate's conditions that require ET tube suctioning is vital. Signs that may indicate a need for suctioning include visible secretions in the ET tube, adventitious or decreased breath sounds, changes in vital signs, decreased oxygen saturation, decreased chest wall movement, and decreased chest wall vibration when the neonate is on HFOV.[1]

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Mechanical Ventilation: Neonate (Respiratory Therapy)

15. Remove gloves and perform hand hygiene.
16. Document the procedure in the neonate's record.

MONITORING AND CARE

1. Review the ventilator settings at the beginning of each shift and with every vital sign assessment.
2. Confirm the activation of all alarms at the beginning of each shift.
3. Auscultate breath sounds and monitor chest excursion, spontaneous effort, air entry, and the neonate's color with ventilator checks or changes and as needed. Monitor chest vibrations when the neonate is undergoing HFOV.
4. Monitor signs and symptoms of changes in oxygenation and ventilation, including lung sounds and aeration of lung segments, vital signs, oxygen saturation as appropriate, ABG or capillary blood gases, cyanosis, WOB, adequacy of chest excursion, and chest radiography findings.
5. Monitor and document oxygen saturation per the organization's practice
6. Monitor blood gases as indicated. (In general, ABGs are obtained within a few hours after initiation of assisted ventilation, after significant changes in ventilation settings, and with changes in the neonate's condition.)
7. Provide oral care when performing hands-on care, usually a few times a day.
8. Confirm ET tube stability and centimeter marking at the gumline or lip line once per shift and as needed.
9. Respond immediately to ventilator alarms and watch for changes and fluctuations in prescribed settings, which may indicate water in the tubing or the need for suctioning.

    Rationale: An alarm may be associated with the need for suctioning or the need to drain water from the tubing, or it may indicate that the ventilator tubing has been disconnected.

10. Monitor for signs of unplanned extubation, including sudden deterioration in clinical status, abdominal distention, crying, decreased chest wall movement, breath sounds in the abdomen, agitation, cyanosis, or bradycardia.
11. Observe the neonate 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 $PaCO_2$
- Oxygenation and ventilation without lung injury
- Hemodynamic stability
- Proper placement of ET tube
- Mobilization and removal of secretions
- Weaning from and termination of mechanical ventilation as soon as neonate is physiologically ready

UNEXPECTED OUTCOMES

- Inadequate ventilation and oxygenation (hypoxemia, hypercarbia, acidosis, alkalosis)
- Lung overinflation (air-leak syndrome)
- Acute lung injury (barotrauma, volutrauma, or progression of lung disease)
- Atelectasis

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Mechanical Ventilation: Neonate (Respiratory Therapy)

- Hemodynamic instability
- Unplanned extubation or malposition of ET tube
- Ventilator-associated pneumonia
- ET tube obstruction
- Inadequately managed pain and agitation due to presence of ET tube or hypoxemia

DOCUMENTATION

- Cardiopulmonary assessment
  - Vital signs
  - Lung sounds
  - WOB
  - Capillary or arterial blood gases
  - Pulse oximetry
- Date, time, and response to initiation of ventilator assistance
- Conventional ventilator settings, if appropriate, including F_{IO_2}, mode, V_T, intermittent mandatory ventilation, PIP, rate, and PEEP
- HFV settings, if appropriate, including F_{IO_2}, amplitude, frequency, and MAP
- Timing of suctioning
- Characteristics of ET tube secretions
- Neonate's response to suctioning
- Assessment of breath sounds after suctioning
- Additional interventions and neonate's response
- Comfort assessment and any specific interventions provided
- Family education
- Unexpected outcomes and related interventions

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ADDITIONAL READINGS

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Supplies

- Gloves
- Neonatal stethoscope
- Conventional mechanical or high-frequency ventilator
- Pulse oximeter
- Cardiopulmonary monitor
- Suction source
- Suction catheters

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Mechanical Ventilation: Neonate (Respiratory Therapy)

- Oxygen and air sources
- Oral-care supplies: gauze, sterile water
- Appropriate-size manual ventilation bag or manual resuscitator, mask, and suction

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