ELSEVIERClinical Skills

Mechanical Ventilation: Neonatal Time-Triggered, Pressure-Limited, and Time-Cycled (Respiratory Therapy)

ALERT

Because of its invasive nature, mechanical ventilation has inherent risks, including infection, barotrauma, volutrauma, bronchopulmonary dysplasia, and lung injury from repeated collapsing and reopening of the alveoli.[1]

Increased levels of supplemental oxygen during mechanical ventilation can result in retinopathy of prematurity and lung injury from excessive arterial oxygen tensions.

OVERVIEW

Time-triggered, pressure-limited, and time-cycled mechanical ventilation is a mode that the respiratory therapist (RT) sets to provide a continuous flow of heated and humidified air to the neonate through positive pressure ventilation via an artificial airway. This mode of mechanical ventilation is used to support or improve ventilation and oxygenation.

Most neonates are ventilated because of immaturity of lung tissue or hyaline membrane disease. The primary goal of mechanical ventilation is to support breathing and oxygenation while using protective lung strategies to minimize potential damage to the neonate's lungs.[1]

Time-triggered, pressure-limited, and time-cycled mechanical ventilation is achieved using ventilators specifically designed to ventilate neonates using this mode. These ventilators require capabilities including the ability to generate low tidal volumes (V_T) and low flows and to sense low-flow and low-pressure changes and other very small dynamic changes generated by the neonate.

With time-triggered, pressure-limited, and time-cycled mechanical ventilation, inspiration is triggered by time. Expiration is also cycled or initiated by time. However, the breath is limited by pressure, and when a certain pressure is reached, the unnecessary flow is diverted away from the neonate.

EDUCATION

- Provide individualized, appropriate education to the family based on the desire for knowledge, readiness to learn, and overall psychosocial state.
- Explain the purpose and complications of mechanical ventilation.
- Describe and explain 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.

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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 risks and benefits of the procedure.
6. Auscultate breath sounds before placing the neonate on mechanical ventilation and assess his or her chest radiograph for tube placement.
7. Check for adequate chest rise and for breath sounds in all lung fields.
8. Assess vital signs and peripheral oxygen saturation (SpO_2).

Preparation

1. Ensure that all necessary emergency equipment is at the neonate's bedside, including a manual resuscitation bag (MRB) with an appropriate-size mask, pressure manometer (if not built into the MRB), and suction equipment.
2. Ensure that the endotracheal (ET) tube is secured to the neonate with appropriate tape or a commercially available securing device.
3. Ensure that the neonate is properly positioned with the head of the bed elevated at least 30 degrees,[2] unless contraindicated.

> Rationale: Elevating the head of the bed reduces the risk of ventilator-associated pneumonia.

4. Ensure that the ventilator has been appropriately self-tested as recommended by the manufacturer.
5. Ensure that the ventilator circuit and humidification device are appropriately assembled on the ventilator and that they are ready for attachment to the neonate.
6. Ensure that all necessary connections are made to connect the ventilator to medical air, oxygen, and electricity.
7. Ensure that all the ventilator alarms are functioning appropriately.
8. Ensure that the ventilator monitor is functioning properly.
9. Ensure that the ventilator circuit humidification system is turned on and heating properly with water in the heater chamber.

PROCEDURE

1. Perform hand hygiene and don gloves.
2. Verify the correct neonate using two identifiers.
3. Explain the procedure to family members and ensure that they agree to treatment.
4. Ensure that the ventilator is turned on and is close to the neonate.
5. Set the initial ventilator settings and adjust them either in collaboration with an authorized practitioner or by following the organization's practice.

a. Adjust the peak inspiratory pressure (PIP) until the neonate's chest rises.

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Rationale: A useful clinical indicator of adequate PIP is a gentle chest rise with every breath; a gentle chest rise indicates that the neonate has normal chest excursion and adequate breath sounds.

Use the lowest possible PIP to achieve adequate gas exchange and visible chest rise.

Avoid excessive PIP to minimize barotrauma.

b. Avoid mean airway pressures greater than 15 cm H_2O.[2] If pressure greater than 15 cm H_2O is needed, consider high-frequency oscillatory ventilation.
c. Set the positive end-expiratory pressure (PEEP) between 5 and 8 cm H_2O.[2]
d. Set a short inspiratory time with an inspiratory:expiratory (I:E) ratio of 1:2.[2]
e. Set the mandatory rate as prescribed by the practitioner or the organization's practice.
f. Set the fraction of inspired oxygen (FIO_2) to achieve the desired arterial oxygen saturation (SaO_2).
g. Assess radiographic findings and arterial blood gas analysis (ABG) results to determine the appropriateness of the settings.

6. Attach the ventilator circuit to the neonate via the ET tube adapter. Stabilize the ventilator circuit so it is not pulling on or putting tension on the ET tube.
7. Perform a complete neonate ventilator system check by checking all initial ventilator and alarm settings, the neonate's spontaneous efforts, and the depth of the ET tube.
8. Ensure that appropriate alarm parameters are set, including low PIP, high PIP, low V_T, high V_T, high respiratory rate, low minute ventilation, and high minute ventilation.

Rationale: Changes in lung compliance can alter the V_T delivered to the neonate and cause volutrauma or hypoventilation.

9. Observe the neonate for signs and symptoms of increased work of breathing or asynchrony.
10. Ensure that the ventilator circuit, inline suction catheter (if applicable), and other respiratory-related tubing are properly positioned and are not pulling, pushing, or placing undue pressure on the ET tube or forcing it against the neonate's gums or soft palate. The ET tube should reside midline in the mouth with no pressure on the upper or lower lip or gum. No tension should be on the ET tube unless ordered by the practitioner.

Rationale: Pressure on the neonate's lips or gums from the ET tube results in breakdown in the area of contact. Tension or pressure on the tube can result in unplanned extubation or right main stem intubation.

11. Remove gloves and perform hand hygiene.
12. Document the procedure in the neonate's record.

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MONITORING AND CARE

1. Review the neonate's current chest radiograph for ET tube placement, lung expansion, and signs of disease (e.g., respiratory distress syndrome, pneumonia, pneumothorax).
2. Perform routine neonate ventilator system checks per the organization's practice.
3. Monitor all activated alarms and address all reasons why they were activated. If the alarms are activated, disconnect the ventilator from the neonate to rule out equipment malfunction while manually ventilating the neonate.
4. Monitor ET tube placement by documenting the centimeter mark at the gum line and monitor skin integrity around the tape and tube-securing device at least once per shift.
5. Monitor the neonate for signs and symptoms of changes in oxygenation and ventilation, including lung sounds.
6. Monitor the neonate's need for ET tube suctioning and other therapeutic interventions.
7. Monitor the neonate for hypoxemia, hypercarbia, asynchrony, changes in chest wall compliance, and readiness to wean.
8. Monitor the neonate's vital signs, Spo_2, skin color, work of breathing, adequacy of chest excursion, and chest radiography findings.
9. Monitor Sao_2 values as needed.
10. Monitor ABG values as indicated. In general, blood gas specimens are obtained after initiation of assisted ventilation, after significant changes in ventilation settings, and with changes in the neonate's condition.
11. Monitor the neonate for signs of auto-triggering or auto-PEEP or other signs of ventilator dyssynchrony.
12. Monitor any fluctuation or trends in ventilator measurements, such as V_T, minute ventilation, or other trends that may signify a need for changes in ventilator support.
13. Provide oral care when performing hands-on care.
14. Respond immediately to ventilator alarms and watch for changes and fluctuations in prescribed settings that can mean water in the tubing or a need for suctioning. Increasing or decreasing V_T at any given PIP indicates changes in lung compliance. If the low-pressure or low-volume alarm sounds, disconnect the neonate from the ventilator and attempt to manually resuscitate him or her with an MRB at the same PIP as the PIP set on the ventilator.

    Rationale: An alarm may be associated with the need for suctioning, the need to drain water from the tubing, or a disconnection of the tubing.

15. Monitor the neonate 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.
16. 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

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- Maintenance of adequate pH and arterial partial pressure of carbon dioxide
- Oxygenation and ventilation without lung injury
- Hemodynamic stability
- Proper placement of ET tube
- Mobilization and removal of secretions
- Discontinuance of mechanical ventilation as soon as the 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
- Hemodynamic instability
- Unplanned extubation or malposition of ET tube
- Ventilator-associated pneumonia
- ET tube obstruction
- Inadequately managed pain and agitation from the ET tube or hypoxemia

DOCUMENTATION

- Family education
- Cardiopulmonary assessment
  - Vital signs
  - Lung sounds
  - Work of breathing
  - Capillary or arterial blood gas results
  - Sa_{O_2}
  - Sp_{O_2}
- Tube placement and centimeter marking at level of the neonate's gums
- Date and time of and the neonate's response to initiation of ventilator assistance
- Ventilator settings
  - F_{IO_2}
  - Set rate
  - Total rate
  - PIP
  - Inspiratory time
  - V_T generated
  - Minute ventilation
  - I:E ratio
  - PEEP
- Alarm settings
- Characteristics of ET tube secretions
- Neonate's response to suctioning
- Assessment of breath sounds after suctioning
- Additional interventions and neonate's response

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- Comfort assessment and interventions
- Unexpected outcomes and related interventions

REFERENCES

1. Arca, M.J., Uhing, M., Wakeham, M. (2015). Current concepts in acute respiratory support for neonates and children. *Seminars in Pediatric Surgery, 24*(1), 2-7. doi:10.1053/j.sempedsurg.2014.11.001
2. Chipman, D.W. (2017). Chapter 53: Neonatal and pediatric respiratory care. In R.M. Kacmarek, J.K. Stoller, A.J. Heuer (Eds.), *Egan's fundamentals of respiratory care* (11th ed., pp. 1216-1248). St. Louis: Elsevier.

AACN Levels of Evidence

- Level A - Meta-analysis of quantitative studies or metasynthesis of qualitative studies with results that consistently support a specific action, intervention, or treatment
- Level B - Well-designed, controlled studies, with results that consistently support a specific action, intervention, or treatment
- Level C - Qualitative studies, descriptive or correlational studies, integrative reviews, systematic reviews, or randomized controlled trials with inconsistent results
- Level D - Peer-reviewed professional organizational standards with clinical studies to support recommendations
- Level E - Multiple case reports, theory-based evidence from expert opinions, or peer-reviewed professional organizational standards without clinical studies to support recommendations
- Level M - Manufacturer's recommendations only

Supplies

- Appropriate-size neonatal heated wire circuit with humidification device
- MRB with pressure manometer
- Cardiac monitor
- Gloves
- Conventional mechanical ventilator with neonatal capability
- ET tube adapter
- 50 psi(g) medical air source
- 50 psi(g) oxygen gas source
- Inline suction catheter
- Oral care supplies
- Oral suction device
- Pulse oximeter
- Stethoscope (neonatal or pediatric size preferred)
- Suction regulator
- Transcutaneous oxygen monitor

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