Proning Therapy for Patients with ARDS

Prone ventilation is a technique of turning a patient with severe hypoxic respiratory failure from the supine to the prone position to improve oxygenation. This maneuver has been successful in the management of patients with acute lung injury or acute respiratory distress syndrome (ARDS). Proning is most commonly used for mechanically ventilated patients; however, prone positioning has been implemented successfully in non-intubated patients with COVID-19, improving oxygenation and reducing rates of intubation (see *Prone Positioning for Non-intubated patients with COVID-19 ARDS*).

Physiology Review

The severity of ARDS is defined by the degree of hypoxemia and is calculated as the ratio of partial pressure of arterial oxygen tension (PaO_2) or pulse oximetry (SpO_2) to fraction of inspired oxygen (FiO_2). ARDS in intubated patients is subdivided into three main categories (Matthay et al., 2024):

- **Mild**: $200 < PaO_2:FiO_2 \leqslant 300$ mm Hg or $235 < SpO_2:FiO_2 \leqslant 315$ (if $SpO_2 \leqslant 97\%$)
- **Moderate**: $100 < PaO_2:FiO_2 \leqslant 200$ mm Hg or $148 < SpO_2:FiO_2 \leqslant 235$ (if $SpO_2 \leqslant 97\%$)
- **Severe**: $PaO_2:FiO_2 \leqslant 100$ mm Hg or $SpO_2:FiO_2 \leqslant 148$ (if $SpO_2 \leqslant 97\%$)

In the supine position, the lungs are compressed by gravity, the heart, and the diaphragm. This position can cause hyperinflation of alveoli in the ventral lung while causing alveolar collapse (atelectasis) in the dorsal part of the lung (lying closest to the bed). Gravity pushes blood downward toward the poorly oxygenated alveoli in the posterior lung, creating a ventilation/perfusion mismatch. This mismatch is thought to drive rapid deterioration of patients with ARDS.

Prone ventilation improves oxygenation and reduces ventilator-induced lung injury by promoting even distribution of lung volumes and pressures throughout the lung. Studies have shown prone positioning improves mortality in severe ARDS by 23%. Early initiation of prone ventilation is most effective and should be reserved for the following patients (Malholtra, 2024):

- Severe ARDS (PaO_2/FiO_2 less than 150 mmHg) with FiO_2 greater than or equal to 0.6 and PEEP greater than or equal to 5 cm H_2O **OR**
- Refractory hypoxemia due to ARDS defined as PaO_2 less than or equal to 100 mmHg with a PaO_2 less than or equal to 60 mmHg despite optimization of the ventilator settings on FiO_2 of 1.0 (or 100%)

Gas Exchange in the Lungs (Gordon et al., 2019; Lucchini et al., 2020)			
	Normal Ventilation	**ARDS**	**Prone**
Definition	• Process of air movement into the lungs. • Oxygen and carbon dioxide gas exchange occurs within the alveoli.	• An acute, diffuse, inflammatory lung injury • Symptoms include dyspnea, increasing need for supplemental oxygen, and alveolar infiltrates on chest X-ray.	• A non-invasive maneuver of positioning a patient on their abdomen. • Used to improve oxygenation.

Gas Exchange in the Lungs (Gordon et al., 2019; Lucchini et al., 2020)			
	Normal Ventilation	**ARDS**	**Prone**
Ventilation (V)	• Adequate tidal volume or inspired air is necessary to reach the alveoli. • Influenced by lung compliance, chest wall compliance, and weight of cardiac and abdominal organs.	• Pulmonary edema causes stiff and non-compliant lungs. • Weight of fluid-filled lungs constricts dorsal lung fields, compressing alveoli, decreasing ventilation.	• Reduces lung compression from weight of cardiac and abdominal organs. • Improves lung compliance. • Enhances the ventilation/perfusion (V/Q) ratio.
Perfusion (Q)	• Sufficient blood flow is required to perfuse the alveoli. • Dependent lung fields (dorsal and basal lobes) typically receive greater perfusion in the supine position.	• Atelectasis (collapsed lung tissue) and interstitial inflammation impair V/Q ratio and contribute to hypoxemia.	• Improves alveolar recruitment, particularly in the dependent and anterior lung fields. • Increases functional residual capacity.
Gas exchange at the alveolar level	• Ample alveolar surface area is necessary for gas exchange to occur.	• Decreased surfactant leads to collapsed alveoli. • Fluid in alveoli inhibits gas exchange and oxygenation.	• Increased drainage of pulmonary secretions improves alveolar surface area for gas exchange.

Contraindications to Prone Positioning

Absolute contraindications include (Gordon et al., 2019; Malholtra, 2024):

- Burns or open wounds on the anterior/ventral surface
- Spinal instability
- Unstable fractures, particularly facial or pelvic
- Massive hemoptysis
- Deep vein thrombosis treated for less than 48 hours
- Mean arterial pressure less than 65 mmHg; shock
- Nitric oxide, or almitrine bismesylate
- Use of extracorporeal membrane oxygenation (ECMO)
- Increased intracranial pressure
- Pregnancy (2^{nd}/3^{rd} trimesters)

Relative contraindications include (Malholtra, 2024):

- Cardiac abnormalities: life-threatening arrhythmias, newly placed pacemaker, ventricular assist devices, balloon pumps
- Thoracic or abdominal surgeries

- First 24 hours following tracheostomy
- Facial trauma
- Recent ophthalmic surgery or increased intraocular pressure

Procedure (Gordon et al., 2019; Lucchini et al., 2020)

Here's a video on Prone Positioning for Acute Respiratory Distress Syndrome (ARDS) from Rush University System for Health.

Prior to placing any patient in the prone position:

- Inspect and confirm endotracheal tube (ETT) placement and verify it is secure.
- Ensure all intravenous lines and tubes are secure and have enough length for the rotation.
- Draw arterial blood gas (ABG) and calculate PaO_2/FiO_2 ratios, as ordered.
- Assess vital signs.
- Adequately sedate the patient, as prescribed.
- Gather pillows or foam pads to support head, neck, and shoulders.
- Stop tube feedings and empty ostomy bags, if present.
- Prepare ETT suctioning equipment.
- Determine which direction you will turn the patient (toward the ventilator).
- Assemble the team: five or six people will be needed based on the size of the patient:
    - One to two people at the head of the bed to monitor ETT, intravenous lines and tubes; ideally the respiratory therapist will maintain the airway and lead the team.
    - Two people on both sides of the patient to turn
    - Provider on standby in case the patient requires re-intubation
- Pre-oxygenate the patient with 100% FiO_2.
- Ensure continuous monitoring of pulse oximetry, mixed venous oxygen saturation, end-tidal carbon dioxide, and invasive arterial blood pressure for the duration of the procedure.

Step-by-step approach (Gordon et al., 2019):

- Pull patient to edge of bed furthest from the lateral position to be used while turning.
- Turn patient to lateral decubitus with dependent arm tucked under thorax.
    - Suction airways, as appropriate.
    - Remove ECG leads and patches from chest; reapply on back.
    - Place a new sheet on the side of the bed that the patient will face.
- Turn or logroll patient to prone position and use the sheet to reposition patient to center of bed.
- Ensure patient's face is positioned to one side (toward the ventilator), never face down.
- Confirm ETT is not kinked or migrated.
- Suction airway as appropriate.
- Support the face, shoulder, and arms for patient comfort (Lucchini et al., 2020).
    - Place the patient's head on a C-shaped pad to prevent facial pressure injuries.
    - Position limbs to prevent abnormal extension or flexion against shoulders and elbows; use pillows for additional support of hips, shoulders, and face.
    - Rolls may be placed under the pelvis and chest in patients with poor neck flexibility, tracheostomy, or both.

- Auscultate chest to ensure proper ETT placement; adjust lines and drains; re-zero the transducers and verify ventilator settings.

Nursing Considerations

- Monitor sedation level and administer neuromuscular blockage, as prescribed.
  - Patients may require additional sedation to tolerate the prone position.
  - If patients continue to have ventilator dyssynchrony despite optimizing ventilator settings and sedation, consider a neuromuscular blocking agent.
- Adjust patient position to relieve pressure points, minimize pressure injuries and maximize secretion mobilization.
  - Turn head from side to side every four hours and reverse the positioning of the patient's arms.
  - Assess for pressure injury.
  - Apply hydrocolloid dressing to high-risk areas: face, thorax, iliac crests, and tibial plateau (Lucchini et al., 2020).
- Volume-controlled and pressure-controlled modes are typically delivered in the prone position.
- For patients with ARDS, ventilation strategy typically includes low tidal volumes (Malholtra, 2024).
- A positive patient response occurs when there is a sustained increase in PaO_2 by 10 mm Hg or more on stable FiO_2 or ventilator settings (Malholtra, 2024).
- Studies show that longer proning time (12-16 hours) has resulted in better outcomes (Lucchini et al., 2020).
- Ensure proper nutrition is maintained and monitor for aspiration.
- Monitor for potential complications (Gordon et al., 2019; Malholtra, 2024):
  - Increased secretions
  - Accidental removal of chest tube, central venous catheter, arterial line, thoracic or abdominal drains
  - Accidental extubation
  - Pressure injuries
  - Aspiration
  - Cardiac arrhythmias, cardiac arrest, hypotension
  - Transient oxygen desaturation
  - Pneumothorax
  - Facial edema
  - Vomiting

References

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