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Mechanical Ventilation in Adults with ARDS

About the Guideline

- Developed by a multi-disciplinary committee representing the American Thoracic Society, the European Society of Intensive Care Medicine and the Society of Critical Care Medicine.
- Objective is to evaluate the latest available evidence on mechanical ventilation strategies in patients with acute respiratory distress syndrome (ARDS) and make recommendations based on the available information with the potential to improve outcomes in this patient population.
- Six major foci surrounding mechanical ventilation in patients with ARDS were addressed in the form of clinical questions from which recommendations were surmised. These areas of focus included the following: lower tidal volume (LTV) and low inspiratory pressure ventilation, prone positioning, high-frequency oscillatory ventilation (HFOV), positive end expiratory pressure (PEEP) strategies, recruitment maneuvers (RMs), and extracorporeal membrane oxygenation (ECMO).

Key Clinical Considerations

Background

- Definition of ARDS: a type of diffuse, inflammatory lung injury, leading to increased pulmonary vascular permeability, increased lung weight and loss of aerated lung tissue (Ranieri et al., 2012).
- Associated with high morbidity and mortality affecting close to 200,000 individuals per year and responsible for 74,500 deaths per year in the United States (Rubenfeld et al., 2005).
- Clinical manifestations:
    - Life threatening acute hypoxic respiratory failure
    - Radiographic appearance of diffuse bilateral opacities (Howell & Davis, 2018).
        - Opacities are the result of neutrophil, macrophage, and dendritic cell mediated tissue damage in the alveoli.
        - In the setting of overall inflammatory state of the acute illness:
            - Increased vascular permeability
            - Release of inflammatory cytokines
            - Accumulation of protein rich fluid in the alveoli resulting in impaired gas exchange (Han & Mallampalli, 2015) and subsequent hypoxia
            - Diffuse alveolar damage
        - Alveolar damage increases physiologic dead space and increases lung compliance

- Conditions associated with the development of ARDS:
    - Sepsis from either a pulmonary or non-pulmonary source accounts for 79% of cases (Rubenfeld et al., 2005).
    - Other conditions: aspiration, pneumonia, toxic inhalation, lung contusion, trauma, acute pancreatitis, blood product transfusion, burn injury, drowning related lung injury, cardiopulmonary bypass (Howell & Davis, 2018; Rubenfeld et al., 2005).
    - Not all those that develop the above conditions go on to develop ARDS.

- Treatment:
  - Supportive
    - Limited evidence-based therapies known to reduce mortality and treatment remains supportive.
    - Mechanical ventilator support is the cornerstone of therapy.
      - May further potentiate lung injury.
  - Continued treatment of underlying issues that led to development of ARDS.

The Berlin definition of ARDS (Ranieri et al., 2012)

- Timing
  - Within one week of clinical insult or new or worsening respiratory symptoms.
- Imaging
  - Bilateral opacities not explained by effusion, lobar/lung collapse or nodules.
- Origin of edema
  - Respiratory failure cannot be fully explained by cardiac failure or volume overload.
    - Consider ECHO or further evaluation of hydrostatic etiologies of pulmonary edema if not risk factors.
- Oxygenation (degree of hypoxemia) and classification of ARDS (Ranieri et al. 2012)
  - Mild - PaO2/FiO2 ratio of 201-300 mmHg with PEEP or CPAP ≥ 5cm H_2O
  - Moderate - PaO2/FiO2 ratio of 101-200 mmHg with PEEP ≥ 5cm H_2O
  - Severe - PaO2/FiO2 ratio ≤ 100 mmHg with PEEP ≥ 5cm H_2O

Recommendations for Mechanical Ventilation in the Management of ARDS

- All patients with ARDS
  - Lower tidal volume mechanical ventilation (4-8 ml/kg predicted body weight) and lower plateau pressures < 30cm H_2O
  - Prone positioning for > 12 hours/day in those with severe ARDS
- Patients with moderate to severe ARDS
  - Higher PEEP as opposed to lower PEEP
  - Recruitment maneuvers (RMs)
  - Both higher PEEP and RMs are thought to decrease atelectasis and improve end-expiratory lung volumes.

Recommendation against the routine use of high frequency oscillatory ventilation in those with moderate to severe ARDS (Fan et al. 2017).

There is *no specific recommendation for or against* the use of ECMO for patients with severe ARDS, citing the need for additional research.

Understanding the Recommendations

To best understand and interpret the recommendations for ARDS, the following concepts regarding mechanical ventilation should be understood.

- Low tidal volume ventilation (also referred to as long protective ventilation)

  - Refers to target tidal volumes of 4 to 8 mL/kg of predicted body weight in patients with ARDS as opposed to traditional ventilator tidal volume goals ranging between 8-12 mL/kg.
  - Target inspiratory plateau pressure $\leq$ 30 cm H_2O
    - Plateau pressure: the pressure applied to small airways and alveoli (a measurement of compliance), measured at the end of inspiration during an inspiratory pause (when there is no flow in the circuit).
  - May require permissive hypercapnia
    - A ventilator strategy in which there is expected hypoventilation of the alveoli which can minimize alveolar hyperinflation and ventilator associated lung injury.

- Prone Positioning
  - Involves placing patient in prone position while on ventilator, shifts weight of heart to ventral wall.
    - Goals:
      - Increase gas exchange by recruiting non-aerated alveoli, keeping alveoli open longer.
      - Improves ventilation-perfusion (VQ) matching (delivering oxygen into bloodstream more efficiently).
      - Increases end expiratory lung volume.
      - Decreased ventilator induced lung injury (VILI) via uniform distribution of tidal volume lung recruitment and alteration in chest wall mechanics (Gattinoni, 2013).
  - Prone positioning requires multiple staff members and a high degree of proficiency to facilitate the process.
  - Contraindicated in patients with increased intracranial pressure, severe hemoptysis, pregnancy, recent sternal surgery, new deep vein thrombosis or unstable fracture.

- PEEP (Positive End Expiratory Pressure)
  - Pressure remaining in lungs at end of expiration
  - Keeps alveoli open longer
  - Potential for barotrauma
  - Usually balance PEEP/FiO2 to optimize oxygen while minimizing barotrauma and oxygen toxicity

- Recruitment Maneuvers:
  - A transient, sustained increase in airway pressure with goal to open collapsed alveoli.
  - Requires applying adequate pressure (PEEP) to overcome distending pressure (the difference between airway pressure and pleural pressure) which is enough to open collapsed alveoli.
  - Involves applying high PEEP for a specified time and evaluating improvements in oxygenation.
    - Example: 30-40 PEEP for 30-40 seconds

- Extra-Corporeal Membrane Oxygenation (ECMO):

  - Veno-venous ECMO works by pulling blood from the inferior vena-cava through a circuit (outside of the body) which removes carbon dioxide and oxygenates blood returning it to the venous system via internal jugular vein.
  - Only indicated in severe, refractory respiratory failure, refractory to mechanical ventilation
  - Requires sedation
  - Short term

- High Frequency Oscillation Ventilation (HFOV)
  - Delivery of small tidal volumes (0.1 – 3 ml/kg) at rapid rates (180-900 cycles per minute or 3-15 Hz)
  - Delivered via an oscillatory pump
  - Theoretically promotes maintenance of alveolar recruitment while preventing over distention
  - Not recommended in the treatment of ARDS

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Link to Practice Guideline:

https://www.atsjournals.org/doi/abs/10.1164/rccm.201703-0548ST?url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org&rfr_dat=cr_pub%3Dpubmed