Acute Respiratory Distress Syndrome In the Adult and Pediatric Population

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Acute Respiratory Distress Syndrome (ARDS) is a potentially devastating clinical disorder, affecting critically ill patients of all ages. Hypoxemic respiratory failure is a common characteristic, requiring invasive or non-invasive mechanical ventilation. Mechanical ventilation provides critical support while clinical interventions and recovery time allow potential resolution of the acute disease process. However, clinically inappropriate techniques utilizing mechanical ventilation can further precipitate lung injury and possibly delay or prevent recovery.

Epidemiology
Acute lung injury (ALI) and acute respiratory distress syndrome (ARDS) rely on laboratory, radiologic, and physiologic data to classify its specific diagnosis. Currently, there is no diagnostic test specifically designed for the syndrome (Rubenfeld, 2003). This provides a significant challenge to caregivers, scientists, and researchers, in attempting to pinpoint the incidence and mortality secondary to ALI/ARDS. The prevalence of ALI/ARDS is reportedly 20-50 cases/105 person years for ALI, and 3-8 cases/105 person years for ARDS (Rubenfeld, 2003). Recent studies suggest an occurrence of 10.4% of all ICU admissions, and 23.4% of patients requiring mechanical ventilation (The LUNG SAFE Investigators, 2016). The mortality rate for adults diagnosed with ALI & ARDS is estimated to be 31 to 50 percent (The Acute Respiratory Distress Syndrome Network, 2000), (The LUNG SAFE Investigators, 2016). The estimated frequency of pediatric ALI/ARDS in the United States, Europe, Australia, and New Zealand is 2.0-12.8 cases/105 person years, with overall ALI/ARDS mortality estimated to be 18-27% (Khemani, Smith, Zimmerman, and Erickson, 2015).

Classifications
Historically, clinical presentations of pulmonary edema without heart failure, currently diagnosed as ALI/ARDS, were documented as early as 1821. During the 1950s, with the advent of early mechanical ventilators, the ability to measure pulmonary pressures presented itself. The Vietnam War added the corollary names of DaNang lung, shock lung, and post-traumatic lung (Bernard, 2005). In 1967, Petty and Ashbaugh described acute respiratory distress syndrome, with a clinical presentation of severe dyspnea, refractory
cyanosis, decreased lung compliance, and diffuse alveolar infiltrates (Ashbaugh, Bigelow, Petty, & Levine, 1967). Interestingly, these clinical symptoms continue to be a focal part of current definitions.

The American-European Consensus Conference (AECC) on ARDS established updated medical definitions and diagnostic mechanisms in 1994, adding the PaO2/FiO2 ratio of ≤ 300 mmHg for ALI, a PAWP of ≤ 18 mmHg or no evidence of left atrial hypertension, and a PaO2/FiO2 ratio of ≤ 200 mmHg for ARDS (The Consensus Group Committee, 1994). A second consensus conference in 1998 yielded recommendations for ventilation, pharmacologic, and supportive therapy, such as minimizing oxygen toxicity (maintain FiO2 ≤ 0.65), achieving sufficient alveolar recruitment with PEEP, minimizing high airway pressures (plateau pressure of 30-40 cmH2O), and judicious use of sedation and paralytic medications (The Consensus Committee, 1998).

The ARDS Network published groundbreaking research in 2000, building on the thoughts and recommendations of the AECC group. The ARDS Network investigators strictly delivered tidal volumes of 6-8 ml/kg of ideal body weight while maintaining plateau pressures ≤ 30 cmH2O, therefore decreasing mortality by 8.8% and increasing ventilator-free days and subsequent number of days breathing without assistance (The Acute Respiratory Distress Syndrome Network, 2000).

During the investigation, the ARDS Network enlisted a very low number of trauma patients. This patient population experiences a clinical and biological difference in lung injury when compared to other lung-injured patients (Calfee, Eisner, and Ware, 2007). Injury Severity Score (ISS), earlier onset of ARDS, pulmonary mechanics, mean intubation days, inflammatory states, and multiple organ failures significantly elevated the mortality in trauma patients (Dicker, Morabito, Pittet, Campbell, and Mackersie, 2004).

In 2013, in an effort to establish more specific and sensitive criteria of the AECC definitions, the ARDS Definition Task Force produced a new set of classifications. The new recommendations, called the Berlin Definition, added timing of presentation (within 1 week of insult), bilateral opacities on frontal chest film or CT scan, implementing echocardiography to rule out hydrostatic edema, and utilizing the PaO2/FiO2 ratio to classify ARDS as mild, moderate, or severe. The new classification of mild (PaO2/FiO2 ratio of < 200 mmHg & PEEP/CPAP of > 5 cmH2O), moderate (PaO2/FiO2 ratio of 100-200 mmHg & PEEP/CPAP of > 5 cmH2O), or severe (PaO2/FiO2 ratio of < 100 mmHg & PEEP/CPAP of > 5 cmH2O) provided better predictability for mortality and resource allocation (The ARDS Definition Task Force, 2012). With the new definition in place, autopsy results of patients that met the clinical criteria for ARDS patients exhibited significantly increased diffuse alveolar damage (DAD) with increased severity of ARDS, suggesting the Berlin definition
offers a high sensitivity, but a low specificity (Thille, et al., 2013).

Pediatric clinicians have historically used the AECC guidelines for diagnosis and classification. The limitations of the AECC guidelines, when applied to pediatric ARDS, lead to the development of the Pediatric Acute Lung Injury Consensus Conference (PALICC) in 2015. PALICC streamlined the Berlin ARDS definition of the official pediatric ALI/ARDS diagnosis. This pediatric-specific Berlin definition simplified the radiologic identification for ALI/ARDS, addressed the co-existence of ALI/ARDS with left ventricular dysfunction/failure, and implemented the oxygenation index in place of the PaO2/FiO2 ratio for patients receiving invasive mechanical ventilation (Khemani, Smith, Zimmerman, and Erickson, 2015).

**Pathophysiology**

ARDS clinically presents as respiratory failure, hypoxemia, diffuse non-hydrostatic pulmonary edema, pulmonary infiltrates, and atelectasis (Albert, Kubiak, and Nieman, 2008). Multiple mechanisms can initiate the clinical manifestation of ARDS, but the developing lung injury usually presents itself with increased permeability of the alveolar-capillary membrane, subsequently leading to the development of pulmonary edema and plasma proteins invading the alveolar spaces; thus creating an environment that can lead to surfactant inhibition and decreased lung compliance. In addition, the increased alveolar permeability and edema/protein leakage into the alveolar space can inaugurate and exacerbate proteases, leukotrienes, and pro-inflammatory mediators, which can intensify injury and amplify inflammation (Lionetti, Recchia, & Ranieri, 2005), (Albert, Kubiak, and Nieman, 2008). During the disease progression, consequent damage can occur to the type-II epithelial cells, which produce surfactant, leading to increased alveolar instability and atelectasis (Albert, Kubiak, and Nieman, 2008).

Trauma associated lung injury emerges as a different pathological process, compared to non-trauma presentations. Trauma patients are typically younger and embody less acute/chronic illnesses that may exacerbate ALI (Calfee, Eisner, and Ware, 2007) (Navarrete-Nevarro, et al., 2001). Shock injury patients with ALI, demonstrated lower levels of the lung epithelial, endothelial injury markers, intercellular adhesion molecule-1, von Willebrand factor antigen, surfactant protein-D, and soluble tumor necrosis factor receptor-1, compared to patients who suffer from other risk factors to lung injury. The lower levels of endothelial and epithelial injury within the lung may explain the difference in the mortality rate at the 90 day mark in trauma patients. (Calfee, Eisner, and Ware, 2007).

**Conventional ventilation strategies**

Conventional mechanical ventilation strategies for treatment of ALI/ARDS, focus on ideal body weight adjusted tidal volume settings to minimize volutrauma and close monitoring of
plateau pressures to reduce barotrauma. Alveolar protective ventilation utilizing appropriate positive-end expiratory pressure (PEEP) minimizes atelectasis and shearing injury. In addition, adjusting FiO2 to an ideal level of ≤ 0.65 might prevent oxygen toxicity and diminish the oxidative effects within the lung (The Consensus Committee, 1998), (The Acute Respiratory Distress Syndrome Network, 2000), (Kallet, 2004), (Brower & Rubenfeld, 2003), (Albert, Kubiak, and Nieman, 2008). In a retrospective ARDS network study, transpulmonary driving pressure (plateau pressure-PEEP) required to generate effective ideal body weight based tidal volumes have been shown to correlate strongly with mortality (Kassis, Loring, and Talmor, 2016). The condition of high transpulmonary pressures can exist in patients already receiving lung protective low tidal volume strategies.

Recruitment maneuvers in ARDS patients may address the cyclic alveolar opening and closing, by recruiting collapsed alveoli and providing improved application of sufficient PEEP. There are multiple approaches to lung recruitment, but ARDS recruitment remains highly variable. While adjusting PEEP, it is important to take into account the patient’s pulmonary mechanics and driving pressure, in conjunction with oxygenation improvements with a lung-protective approach (Hess, 2015).

Airway Pressure Release Ventilation (APRV) is a time triggered, time cycled, pressure controlled mode of mechanical ventilation that caters to spontaneous breathing at any point of the breath cycle. APRV is often referred to as “CPAP with a release” – a high level of sustained CPAP to affect oxygenation, with periodic short releases to a lower CPAP level, to facilitate ventilation (Frawley and Habashi, 2001). APRV may improve patient ventilator synchrony, hemodynamic parameters, and also require less sedative agents. In contrast, APRV can subject ARDS patients to high transpulmonary pressures, excessively larger tidal volumes, and cyclical de-recruitment during release breaths (Mejía, Fan, and Ferguson). More research is required to establish a clear set of guidelines for APRV implementation and management.

**Hamilton Medical technology**

Hamilton Medical offers multiple solutions for lung-protective approaches in patients with ALI/ARDS, providing safe care for patients by facilitating caregiver comfort and efficiency.

**Adaptive Support Ventilation (ASV®)** is a Hamilton proprietary mode of ventilation that employs lung-protective strategies of ventilation based on the ideal body weight of patients and minimizes complications from volutrauma and barotrauma by application of the Otis and Mead equations. ASV automatically implements lower tidal volumes and drive pressure in proportion to the severity of ARDS. ASV also prevents deadspace ventilation and excessively large tidal volumes (Agarwal, Srinivasan, Aggarwal, and Gupta, 2013).

The Hamilton Medical **Protective Ventilation (P/V) Tool** allows clinicians to perform a
pulmonary mechanics maneuver by implementing a quasi-static pressure/volume curve that displays both the inflation and deflation portions of the pressure/volume loop. P/V Tool plots the inflection points, displays the PV loop hysteresis and the inflation/deflation limb compliances aiding the clinician’s analysis of pulmonary mechanics and optimizing PEEP levels to prevent the repetitive alveolar opening and closing (Borges, et al., 2006), (Arnal, et al., 2011). Presence of a lower inflection point, the convex shape of the inflation limb and significant hysteresis are predictive of a recruitable lung. As the Hamilton Medical P/V Tool utilizes a unique pressure ramping technique, additional settings allow for the P/V Tool to be used to perform recruitment maneuvers.

The transpulmonary pressure measurement available on Hamilton Medical ventilators allows clinicians to insert an esophageal balloon catheter into the lower third of the esophagus, in conjunction with lung zone three. The ability to measure esophageal pressures (a surrogate for pleural pressure) in correlation with ventilator airway pressures allow clinicians to perform more effective recruitment maneuvers, optimize set/adjust PEEP to prevent atelectrauma, and fine-tune tidal volumes to minimize excessive transpulmonary driving pressures (Talmor, et al., 2008).

References


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