Lung-protective Ventilation Strategies and Adjunctive Treatments for the Emergency Medicine Patient with Acute Respiratory Failure

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KEYWORDS

- Acute respiratory failure • Acute respiratory distress syndrome
- Mechanical ventilation

KEY POINTS

- Respiratory failure is a frequent disease process encountered in the emergency department.
- There is significant need for improvement in the care of patients on mechanical ventilation. If not contraindicated, lung-protective ventilation strategies should be used.
- Patient specific disease pathophysiology is important to consider when treating patients that are difficult to oxygenate, ventilate or when Pa_{O_2}, Pa_{CO_2}, and/or pH can only be maintained at unsafe ventilator settings.

INTRODUCTION

Invasive mechanical ventilation (MV) is an essential component of critical care and emergency medicine (EM). Successful resuscitation requires an expedient and parallel assessment of airway maintenance, efficiency and effectiveness of breathing mechanics, and adequacy of circulation and perfusion. Management should be directed at ensuring sufficient oxygenation, ventilation, and prompt reversal of the inciting disease process if possible. This article reviews the evidence for safe MV strategies in the critically ill patient in the emergency department (ED) and provides treatment options for patients who are difficult to oxygenate and ventilate or cannot safely be managed with standard MV strategies.

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EPIDEMIOLOGY/STATEMENT OF THE PROBLEM

Acute respiratory failure (ARF) requiring MV is a common clinical scenario. Wunsch and colleagues[1] suggested that approximately 3% of all hospital admissions in the United States require invasive MV. MV costs approximately $27 billion dollars nationally.[1] Nearly one-third of patients who are placed on MV die in the hospital and among survivors only 30% are discharged home after their admission.[1] Recent data suggest opportunities for improvement because many patients in the ED and intensive care unit (ICU) do not get optimal MV therapy for ARF.[2,3]

PATHOPHYSIOLOGY

Breathing is essential for homeostasis. In critically ill patients the demands for oxygen supply and carbon dioxide removal are often increased. This increased demand can be superimposed on prior impaired cardiopulmonary reserve. In ARF the cardiopulmonary system fails to oxygenate or ventilate adequately or inefficient breathing mechanics put excessive loads on the cardiopulmonary system. MV is used to offload respiratory muscle work and assist in oxygen delivery and ventilation.

OXYGENATION AND HYPEROXIA

Most oxygen is carried by hemoglobin molecules in red blood cells. MV is often used to correct hypoxemia (low oxygen saturation) to improve total blood oxygen content. In emergent situations it is beneficial to increase the fraction of inspired oxygen (FiO_2) to increase blood oxygen content. Increased FiO_2 should only be considered as a temporary fix because there are downsides to high concentrations of FiO_2.

First, in patients with normal lungs, supernormal FiO_2 concentrations lead to hyperoxia or a PaO_2 greater than or equal to 200.[4] Multiple studies suggest that hyperoxia leads to the formation of reactive oxygen species that can cause tissue damage.[4–8] More recent data in brain-injured patients[4,8] and patients after cardiac arrest[9] suggest worse outcomes with hyperoxia versus normal oxygen concentrations. Hyperoxia is an iatrogenic entity that can be avoided by turning the FiO_2 down.

Second, in patients with abnormal lungs, an FiO_2 of 1.0 (100%) can mask the degree of pulmonary dysfunction.[3] A normal oxygen saturation on pulse oximetry can be falsely reassuring.[3] On a FiO_2 of 1.0, a saturation of 100% may correspond with a PaO_2 of between 100 and 500, the latter being normal and the former evidence of significant respiratory dysfunction. Having a through understanding of the magnitude of pulmonary dysfunction may allow better patient care[3] because these patients may be candidates for other adjunctive therapies and lung-protective ventilation strategies (LPVS). Once stabilized and resuscitated through the peri-intubation period, dial down the FiO_2 using pulse oximetry. An oxygen saturation around 95% is sufficient and in certain conditions (chronic obstructive pulmonary disease [COPD], obesity hypoventilation syndrome, and obstructive sleep apnea) a saturation of between 88% and 92% may be more appropriate.[10] Titrating the FiO_2 helps to determine the degree of respiratory dysfunction and helps limit oxygen toxicity.

OXYGEN DELIVERY AND HEART-LUNG INTERACTIONS

Placing a critically ill patient on MV can have serious untoward effects on cardiac output (CO) and oxygen delivery and can lead to adverse events if not appropriately anticipated and managed proactively.[11] In conditions associated with high afterload, MV can be beneficial by decreasing the force opposing left ventricular contraction and left ventricular transmural wall pressure.[11] In preload-dependent states (hypovolemic