High-Frequency Oscillatory Ventilation of the Adult

The acute respiratory distress syndrome (ARDS) is a common, devastating clinical syndrome of acute lung injury (ALI) that affects surgical and medical patients.[1] Recent studies report an incidence ranging from 1.5–8.3 to as many as 75 occurrences per 100,000 patients.[1]

The classic definition of ARDS, defined by Ashbaugh and Petty in 1967, consists of a clinical triad of respiratory distress: cyanosis that is refractory to oxygen therapy, decreased lung compliance, and diffuse pulmonary infiltrates that are evident on a chest radiograph.[2] The definition was expanded in 1988 in response to a lack of specific criteria to systematically identify patients. The expanded definition implemented a four-point lung injury scoring system based on levels of positive end-expiratory pressure, the ratio of the partial pressure of arterial oxygen to the fraction of inspired oxygen (P/F ratio), the static lung compliance, and the degree of infiltration evident on the chest radiograph.[1]

In 1994, new definitions for ARDS were recommended by the American-European Consensus Conference Committee. The new definitions have two advantages. First, they recognize that the severity of clinical lung injury varies. The P/F ratio is retained from the 1988 definition, with delineations for ALI and ARDS. A P/F ratio of 300 or less indicates ALI; a P/F ratio of 200 or less indicates ARDS. Second, the new definitions are easily applied in the clinical arena.

However, there are disadvantages to the new definitions: Factors that affect outcome (e.g., underlying cause, other organ systems involved) are not assessed, and the criteria for the presence of bilateral pulmonary infiltrates on chest radiography consistent with the presence of pulmonary edema are not sufficiently specific to be consistently applied by clinicians.[1,3] Despite the disadvantages, the 1994 Consensus definitions and the 1988 lung scoring system have greatly improved standardization of clinical research and trials.[1] The 1994 Consensus definitions remain the gold standard for ARDS and ALI description.

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The clinical trial by the National Institutes of Health (NIH) and ARDS Network reported a lung protective approach, utilizing lung tidal volumes ≤6 mL/kg of predicted body weight and an inspiratory plateau pressure ≤30 cm H_2O on conventional ventilation (CV).[4] This lung protective approach reduced the absolute mortality by 9% when compared with larger tidal volume (12 mL/kg of predicted body weight) ventilation. Unfortunately, in practice, many critically ill patients with ARDS are unable to achieve adequate gas exchange using conventional lung protective strategies, and the mortality is still extremely high.[5] With proper recognition and intervention, ALI can be reversed in its early stages.[6]

The potential benefits of high-frequency oscillatory ventilation (HFOV) over CV are described in animal studies. HFOV resulted in improved gas exchange, improved lung inflation, and decreased histopathologic ventilation-induced lung injury in surfactant deficient rabbits and primates.[7–10] HFOV reduced cyclical alveolar collapse and over-distension in these studies. This mode of ventilation was associated with reduced levels of inflammatory mediators compared with CV techniques, even with similarly high levels of mean airway pressure.[11–13]

Recent studies and trials

In adult patients with ALI/ARDS, high-frequency oscillatory ventilation has been studied and reported in multiple observational trials and a few randomized controlled trials. The studies demonstrated a significant improvement in oxygenation with utilization of an "open lung" strategy. Improved outcomes were demonstrated when HFOV was implemented early in the ARDS disease process.[14–17]

Fort et al completed a prospective clinical study in 1997 that evaluated the safety and effectiveness of HFOV, utilizing a protocol designed to recruit and maintain optimal lung volume in patients with severe ARDS. This trial, with 17 patients, demonstrated improved gas exchange and an overall improvement in the P/F ratio, along with reductions in the oxygen index and fractional inspired oxygen. In addition, no significant compromise in cardiac output or oxygen delivery was observed, despite a significant increase in the mean airway pressure. The authors concluded that HFOV was both safe and effective in adults with severe ARDS failing conventional ventilation.[18]

Proning, nitric oxide, surfactants, partial liquid ventilation, and hemofiltration/dialysis should be investigated for possible benefits for adult HFOV patients.

Mehta and colleagues completed a prospective clinical study in 2001 that evaluated the safety and efficacy of HFOV in adult patients with ARDS and oxygenation failure in 24 patients. The authors concluded that HFOV has beneficial effects on oxygenation and ventilation and may be a safe, effective rescue therapy for patients with severe oxygenation failure. The authors also concluded that early initiation of HFOV may be advantageous.[19]

Derdak et al completed a multi-center, randomized controlled trial in 2002 comparing HFOV with conventional pressure control ventilation in 148 patients. The trial demonstrated a trend toward reduced mortality in the HFOV arm and a marked improvement in the P/F ratio. The authors concluded that HFOV is a safe and effective mode of ventilation for the treatment of ARDS in adults.[20]

In 2006, Kao et al completed a prospective clinical study evaluating HFOV in 16 surgical patients with severe oxygenation failure who were failing conventional mechanical ventilatory support. The authors concluded that HFOV was again safe and effective in correcting oxygenation failure associated with ARDS in surgical patients.[21]

Cartotto and colleagues completed a retrospective review of 36 severely burned patients, 33% of whom had an associated inhalation injury with significant oxygenation failure secondary to ARDS. The authors concluded that HFOV was an indispensable ventilation modality for burn patients and played an important role in reversal of oxygenation failure in patients with ARDS and in facilitating closure of burn wounds.[22]

The benefits from reduced tidal volume ventilation have been recognized since the NIH ARDSNet trial comparing small and large tidal volumes.[4] There is significant experimental evidence showing that HFOV reduces ventilator-induced lung injury and lung biotrauma in small animal models. The limitations of applying these studies to adult patients stem from the fact that animal studies utilize smaller endotracheal tube sizes, lower amplitudes, and higher frequency settings than are typically utilized in adult patients.[7–9,11–13] Thus, early initiation of HFOV therapy appeared to be beneficial as a lung protective mode of ventilation.

HFOV sustains the lung in an open, recruited state just above the closing point on the exhalation limb of the static pressure-volume curve. This sustained, open state should result in minimal stretch injury due to the small tidal volumes generated by the pressure amplitude excursions and should minimize the potential for atelectasis from repetitive opening and closing of the alveolar lung units at lower tidal volumes.[23,24]

HFOV shows promise but further research needed

High-frequency oscillatory ventilation is a promising alternative mode of mechanical ventilation for severe ALI/ARDS in adult patients. Further research is needed to investigate multiple areas, including measurements of delivered volumes, lung compliance, and distal airway pressures.[25] Adjunctive therapies (e.g., proning, nitric oxide, surfactants, partial liquid ventilation, and hemofiltration/dialysis), all of which have shown to improve oxygenation with HFOV, should be investigated for possible benefits.[26,27] Randomized, controlled trials are needed to provide results on ventilator-free days, reduced ICU/hospital length of stay, and reduced morbidity/mortality. ■

EDITOR'S NOTE

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