INTRODUCTION

Acute respiratory distress syndrome (ARDS) is responsible for significant morbidity and mortality in the critically ill population (1-5). The use of mechanical ventilation in this population is important to sustain life but the goal has shifted dramatically over the last few decades, from aiming to achieve normal blood gases to instead minimizing ventilator-induced lung injury (VILI). The recognition of the critical role that VILI plays in the outcome of adults with ARDS has driven significant interest in alternative modes of ventilation that might be more lung protective. High-frequency ventilation (HFV) is a family of ventilatory modes that falls into this category. High-frequency oscillatory ventilation (HFOV) is the most extensively studied mode, and this chapter focuses on its use in the adult population.

DEFINITIONS, TERMINOLOGY, AND SUBTYPES

HFV is a collection of ventilatory modes, grouped together by their common property of employing high respiratory rates, all greater than 60 breaths/min (6,7). In addition to HFOV, other modes in this group include high-frequency jet ventilation (HFJV), high-frequency percussive ventilation (HFPV), and high-frequency positive-pressure ventilation (HFPPV).

High-Frequency Jet Ventilation

HFJV is a mode of ventilation in which gas is delivered through a small-bore catheter into the lungs at rates of 100 to 150 breaths/min (8). Delivered tidal volume is still small, but higher than just the volume exiting the jet, as the jets entrain an additional flow of gas by the Choanda effect. Exhalation is passive during HFJV; therefore, gas trapping or dynamic hyperinflation can be an issue. In practice, a conventional ventilator is set up as a “slave” to the jet to provide positive end-expiratory pressure (PEEP), along with basic monitoring and alarms.

High-Frequency Percussive Ventilation

HFPV is the newest and least well-studied of the HFV modes. It combines a high-frequency rate of 200 to 900 breaths/min superimposed on a conventional pressure mode of ventilation (17). HFPV is reported to enhance the clearance of respiratory secretions and has been successfully used in this regard in patients with burns and inhalational injury (17,18).

High-Frequency Oscillatory Ventilation

High-frequency oscillation (HFO) is a mode of mechanical ventilation with very high respiratory rates of 3 to 15 Hz (equivalent to 180 to 900 breaths/min), generating very small tidal volumes around a set mean airway pressure (mPaw). Tidal volumes are small with HFO, often smaller than the anatomic dead space, in the range of 1 to 2 mL/kg (19). HFO has been widely and effectively used in neonates and children for close to 30 years (20–24). Only in the late 1990s did this device became available in the adult ICU; previous versions of this ventilator were only capable in oscillating patients under 35 kg. In contrast to other HFV modes, humidification is less of an issue during HFO, as a continuous bias flow of humidified gas is passed in front of an oscillating membrane (Fig. 107.1). Another advantage of HFO over other HFV is its active expiration, which may account for more control of ventilation and CO₂ elimination, and the lack of important gas trapping and hyperinflation (25,26). A resistance valve at the end of the bias flow circuit regulates the mean airway pressure. The elegance of HFO is that it allows for “decoupling” of oxygenation and ventilation. In general, alveolar ventilation, and thus carbon dioxide elimination, is dependent on the frequency and tidal volume but are relatively independent of lung volume (26,27). In contrast, oxygenation is typically proportional to the fraction of inspired oxygen and the mean airway pressure and lung volume (27,28).

PHYSIOLOGY

Mechanisms of Gas Transport during High-Frequency Oscillation

In addition to relying on bulk flow, adequate CO₂ removal during HFO is achieved through a number of alternative
mechanisms including convective streaming due to asymmetric velocity profiles, Pendelluft, cardiogenic mixing, and diffusion (Fig. 107.2). A full explanation of these physiologic principles can be found in a number of papers reviewing this physiology in detail (7,19,29–36). During HFOV, alveolar ventilation is influenced by the frequency of oscillations, the inspiratory/expiratory (I/E) ratio, and the peak-to-peak pressure gradient (delta P) which is generated by the force of the diaphragm movement. The major message from these theoretical and experimental studies is that CO₂ elimination—which is
Tidal Volume and Frequency of Oscillation during High-Frequency Oscillatory Ventilation

Tidal volume is not routinely measured in clinical practice during the use of HFOV but assumed to be low. It is known to be inversely related to frequency due to the decrease in respiratory time with increasing frequency (26). Many investigators have explored this issue reporting tidal volumes in adults with ARDS during HFOV usually range from 1 to 2.5 cc/kg predicted body weight (PBW) (19,37). Changes in delta P have a comparatively smaller effect on tidal volume in adults with ARDS (38,39). The relationship between the frequency of oscillation and the tidal volume generated during HFOV was clearly demonstrated in a recent animal ARDS model when HFOV at frequencies of 3, 6, and 9 Hz generated tidal volumes of 4.8, 2.7, and 1.8 mL/kg, respectively (40). This study also showed that despite application of the same mPaw, higher frequencies were associated with lower transpulmonary pressure. Moreover, higher frequencies of oscillation enhanced the probability of successful reopening of collapsed lung regions leading to a more homogeneous distribution of air within the lung (41). Cumulatively, these data suggest that increasing frequency of oscillation results in tidal volume reduction and highlight the potential importance using higher frequency as tolerated to achieve lower tidal volume and transpulmonary pressure to minimize VILI while avoiding severe respiratory acidosis. Occasionally, partial deflation of the endotracheal cuff to allow for air leak could be used to enhance CO2 clearance.

Mean Airway Pressure, Oxygenation, and the Use of Recruitment Maneuver

Target oxygenation is achieved though the adjustment of FiO2 and mPaw during HFOV. As cyclic alveolar stretch is minimal, clinicians are able to set the mPaw on HFO significantly higher than they are able to set PEEP on conventional ventilation, thereby avoiding cyclic collapse and atelectrauma, and while still being capable of avoiding very high peak inspiratory pressures and subsequent volutrauma (Fig. 107.3). This should allow a larger margin of error, making it easier to stay within the “safe window” of lung protection. There is controversy regarding the optimum method of titration FiO2 and mPaw during HFOV. The use of recruitment maneuvers, sustained inflation maneuvers with 30 to 40 cm H2O pressures for 30 to 40 seconds, have been found to be safe in adults on CMV, but studies have shown mixed results in terms of efficacy, duration of their oxygenation effect, and outcome (42). Because of the small tidal volumes generated with HFO, there is very little tidal recruitment of the lung, creating a more compelling rationale for recruitment maneuvers (RMs) during HFO compared with conventional ventilation (28,43–45).

RATIONAL FOR USE

Mechanical ventilation, although necessary to preserve life, can itself aggravate or cause lung damage, referred to as VILI. The pathophysiologic principles of VILI are complex and overlapping. These include high tidal volumes causing overdistention (volutrauma) (46–54); recruitment and derecruitment of unstable lung units (atelectrauma) (46,55–59); and oxygen toxicity (60,61). All of these mechanisms can lead to the local and systemic release of inflammatory mediators—termed bio-trauma (38,55,56,62–68), which is responsible for the major cause of death in ARDS and multiorgan dysfunction syndrome (MODS) (5,69).

Patients with ARDS are at increased risk of regional lung overdistention because of the patchy nature of ARDS (70,71); the small areas of relatively normal lung (the so-called baby lung) receive the bulk of the tidal volume and are at particular risk of volutrauma (72,73). In addition, animal data suggest that efforts to limit lung unit closing on expiration by maintaining an adequate PEEP are relatively protective against atelectrauma (46,55–59). Here, the paradigm is one of “opening the lung and keeping it open,” thereby avoiding cyclic collapse and recruitment/derecruitment (43,55).

In the mid-1990s, given the expanding animal data on VILI and in light of initial promising, but uncontrolled human studies of lung-protective ventilation, a call was made for randomized trials. The large trial conducted by the National Institutes of Health (NIH) ARDS Network showed important differences in mortality (74). In this study, 861 patients were randomly assigned to receive a low-stretch strategy with a targeted tidal volume of 6 mL/kg PBW and a plateau pressure limit of 30 cm H2O, or to a higher-stretch strategy using a targeted tidal volume of 12 mL/kg PBW and a plateau pressure limit of up to 50 cm H2O. The low-stretch strategy was associated with a mortality reduction from 40% in the control group to 31% in the experimental group. This trial clearly indicates that avoiding volutrauma saves lives in patients with acute lung injury and 6 mL/kg PBW has emerged as a standard for the protective lung ventilation strategy against which other strategies are compared. Furthermore, three large trials have subsequently been conducted comparing higher versus lower levels of PEEP while controlling tidal volumes in all patients...
A few randomized controlled trials evaluated HFOV in ARDS in comparison to conventional ventilation prior to 2013. Two of these trials (92, 93) were planned and started prior to the completion of the first ARDS Network study that showed benefit from strict control of tidal volumes (74). None of the RCTs demonstrated safety concerns. The Multicenter Oscillatory Ventilation for Acute Respiratory Distress Syndrome (MOAT) Trial by Derdak et al. (92) was the first RCT that compared HFOV to conventional ventilation in adults with moderate to severe ARDS. It included 148 patients from 13 university-affiliated medical centers. There were significant improvements in oxygenation with HFOV and an impressive trend toward a mortality benefit with HFOV (RR 0.72; 95% CI 0.50 to 1.04) despite more than 10% of the control group crossing over to HFOV. It is important to recognize that the parameters of the CMV arms of the studies by Derdak et al. (92) and Bollen et al. (93) may have been relatively injurious, having been designed and initiated in the 1990s. The mean tidal volumes applied were high (10.6 mL/kg PBW and 8.1 ± 1.6 mL/kg PBW at 48 hours, respectively). HFOV was considered well tolerated and safe in moderate-to-severe ARDS and warranted the need of larger studies to demonstrate outcome benefit of HFOV.

Multiple meta-analyses of the use of HFOV in adults with ARDS have been published. A 2010 systematic review and meta-analysis (96) included eight trials of HFOV as an initial ventilation strategy for early ARDS with total enrollment of 419 patients with ARDS (PaO2/FiO2 ratio of 112) in seven trials. The analysis showed that there was improvement in oxygenation with an increase in PO2/FiO2 ratio by 16% to 24% and mortality reduction at hospital discharge or 30 days (risk ratio 0.77, 95% CI 0.61 to 0.98, P = 0.03). However, many limitations to these data are implied by the quality of the studies included including the high mortality and injurious higher tidal volumes (>8 mL/kg PBW) in the control group. Although the subgroup post hoc analysis showed a similar benefit in trials that implemented lower tidal volumes (<8 mL/kg) in the control group, the number of patients was considerably low (n = 98) such that solid conclusions could not be generated. These data in conjunction with those derived from the animal studies and theoretical principles, called for the conduction of the larger RCTs.

Randomized Control Trials Published in 2013

The two most recent and largest multicenter RCTs of HFOV in adults with ARDS were published in early 2013. Both the Oscillation for Acute Respiratory Distress Syndrome Treated Early (OSCILLATE) Trial (N = 548) (94) and the Oscillation in ARDS (OSCAR) trial (N = 795) (95) were designed to compare HFOV to a conventional mechanical ventilation strategy in adults with early moderate-to-severe ARDS and revealed interesting results. The two study protocols are compared and contrasted in Table 107.3. The OSCILLATE trial was designed to test the early application of an HFOV strategy targeting lung recruitment with higher mean airway pressures compared with conventional lung-protective mechanical ventilation also targeting lung recruitment with higher PEEP. This trial was stopped early because of increased in-hospital mortality in the HFOV group (47% vs. 35%; relative risk of death with HFOV 1.33; 95% CI 1.09 to 1.64; P = 0.005). Meanwhile, the OSCAR trial compared a different HFOV strategy versus usual care conventional ventilation found no difference between HFOV and CMV in all-cause 30-day mortality (41.7% vs. 41.1%; P = 0.85) and in-hospital mortality (50.1% vs. 48.4%).
### TABLE 107.1 Observational Studies of HFOV in ARDS

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Baseline Characteristics</th>
<th>Design</th>
<th>Mean Time of CMV Prior to HFOV</th>
<th>Complications</th>
<th>Main Findings</th>
<th>Mortality</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fort (81)</td>
<td>17</td>
<td>( \text{PaO}_2/\text{FiO}_2 ): 68.6 ± 21.6 ( \text{OI} ): 49 APACHE II: 23</td>
<td>Prospective</td>
<td>5.12 ± 4.3 d</td>
<td>Barotrauma 6% ETT obstruction 6%</td>
<td>Improved oxygenation</td>
<td>53%</td>
<td>Baseline OI and duration of CMV associated with 1 mortality</td>
</tr>
<tr>
<td>Mehta (82)</td>
<td>24</td>
<td>( \text{PaO}_2/\text{FiO}_2 ): 99 ± 39 ( \text{OI} ): 33 APACHE II: 22</td>
<td>Prospective</td>
<td>5.7 ± 5.6 d</td>
<td>Barotrauma 8% ETT obstruction 4%</td>
<td>Improved oxygenation</td>
<td>67%</td>
<td>HFO appears safe and improves ( \text{O}_2 ) in rescue setting</td>
</tr>
<tr>
<td>Andersen</td>
<td>16</td>
<td>( \text{PaO}_2/\text{FiO}_2 ): 92 ( \text{OI} ): 28 APACHE II: 27</td>
<td>Retrospective</td>
<td>7.2 d</td>
<td>Barotrauma 6%</td>
<td>Improved oxygenation</td>
<td>31%</td>
<td>HFO appears safe and improves ( \text{O}_2 ) in rescue setting</td>
</tr>
<tr>
<td>David (84)</td>
<td>42</td>
<td>( \text{OI} ): 23 APACHE II: 28</td>
<td>Prospective</td>
<td>3 d</td>
<td>Barotrauma 2%</td>
<td>Improved oxygenation</td>
<td>43%</td>
<td>HFO appears safe and improves ( \text{O}_2 ) in rescue setting</td>
</tr>
<tr>
<td>Cartotto</td>
<td>25</td>
<td>Burn patients with ARDS (28% inhalation injury) ( \text{PaO}_2/\text{FiO}_2 ): 98 ± 26 ( \text{OI} ): 27 APACHE II: 16</td>
<td>Retrospective</td>
<td>4.8 ± 4.4 d</td>
<td>Barotrauma 0%</td>
<td>Improved oxygenation</td>
<td>28%</td>
<td>HFO appears safe and improves ( \text{O}_2 ) in rescue setting</td>
</tr>
<tr>
<td>Mehta (86)</td>
<td>156</td>
<td>( \text{PaO}_2/\text{FiO}_2 ): 91 ± 48 ( \text{OI} ): 31 APACHE II: 24</td>
<td>Retrospective</td>
<td>5.6 ± 7.6 d</td>
<td>Barotrauma 21%</td>
<td>Improved oxygenation</td>
<td>62%</td>
<td>Baseline OI and duration of CMV associated with 1 mortality</td>
</tr>
<tr>
<td>Ferguson (87)</td>
<td>25</td>
<td>( \text{OI} ): 23 APACHE II: 24</td>
<td>Prospective, multiple-center, single-intervention pilot study</td>
<td>5.8-50.5 hr</td>
<td>Barotrauma 8-20%</td>
<td>Rapidly improved oxygenation</td>
<td></td>
<td>HFO appears safe and improves ( \text{O}_2 ) in rescue setting</td>
</tr>
<tr>
<td>Finkelman</td>
<td>14</td>
<td>( \text{PaO}_2/\text{FiO}_2 ): 73 ± 20 ( \text{OI} ): 35 APACHE II: 35</td>
<td>Retrospective</td>
<td>1.8 ± 1.1 d</td>
<td>Barotrauma 0%</td>
<td>Improved oxygenation</td>
<td>57%</td>
<td>HFO appears safe and improves ( \text{O}_2 ) in rescue setting</td>
</tr>
<tr>
<td>Fessler (89)</td>
<td>30</td>
<td>APACHE II: 25 ( \text{PaO}_2/\text{FiO}_2 ): 78</td>
<td>Retrospective</td>
<td>3.1 ± 3 d</td>
<td>Barotrauma 20%</td>
<td>Improved oxygenation</td>
<td>63%</td>
<td>Used high frequency &gt;6 Hz (median is 9 Hz)</td>
</tr>
<tr>
<td>Adhikari (90)</td>
<td>190</td>
<td>APACHE II: 28</td>
<td>Retrospective</td>
<td>2 d</td>
<td>Barotrauma 2%</td>
<td>Improved oxygenation</td>
<td>30-d mortality (56%)</td>
<td>No independent predictors of positive oxygenation response to HFOV Reasons for HFOV discontinuation included death or withdrawal of life support (39.1%), significant improvement in respiratory failure (37.6%), and inadequate improvement (23.3%)</td>
</tr>
<tr>
<td>Camporaota</td>
<td>102</td>
<td>APACHE II: 24.1 ( \text{PaO}_2/\text{FiO}_2 ): 93.8 ± 38</td>
<td>Retrospective</td>
<td>45 hr</td>
<td>Barotrauma 2%</td>
<td>Changes in ( \text{PaO}_2/\text{FiO}_2 ) of HFOV helped identify patients that are more likely to survive</td>
<td>30-d mortality (56%)</td>
<td>Improvement of &gt;38% in ( \text{PaO}_2/\text{FiO}_2 ) occurring at any time within the first 72 hr. was the best predictor of survival at 30 d</td>
</tr>
</tbody>
</table>

HFO, high-frequency oscillation; ARDS, acute respiratory distress syndrome; OI, oxygen index; ETT, endotracheal tube; CMV, conventional mechanical ventilation.
TABLE 107.2 Randomized Controlled Trials of HFOV in ARDS

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Baseline Characteristics</th>
<th>Mean Days of CMV Prior to HFOV</th>
<th>Complications</th>
<th>Main Findings</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derek (92)</td>
<td>148</td>
<td>APACHE II: 22</td>
<td>2.8</td>
<td>No significant difference between CMV and HFOV regarding hemodynamic variables, barotraumas, and mucous plugging</td>
<td>Improved oxygenation with HFOV for the first 24 hr</td>
<td>Mortality: HFOV: 37% CV 52%</td>
</tr>
<tr>
<td>Bollen (93)</td>
<td>61</td>
<td>OI: HFOV: 25 CV: 18 APACHE II: 21</td>
<td>2.1</td>
<td>HFOV: hypotension (10.8%), air leak (7.7%) CV: hypotension (4.2%), air leak (4.2%)</td>
<td>Significant improvement in oxygenation initially compared with CMV</td>
<td>No difference in mortality The study was stopped early</td>
</tr>
<tr>
<td>Ferguson (94) (OSCILLATE trial)</td>
<td>548</td>
<td>APACHE II: 29 (both groups) PaO2/FIO2: HFOV: 121 ± 46 CMV: 114 ± 38</td>
<td>HFOV: 2.5 ± 3.3 CMV: 1.9 ± 2.3</td>
<td>HFOV group required more vasopressors (91 vs. 84%), higher doses of midazolam (199 vs. 141 mg/d), and had more paralyses (83 vs. 68%) than CMV group</td>
<td>Mortality was higher in the HFOV group as compared to CMV (47 vs. 35%)</td>
<td>41.7% in the HFOV group and in 163 of 397 patients (41.1%) in the conventional ventilation group (P = 0.18)</td>
</tr>
<tr>
<td>Young (95) (OSCAR)</td>
<td>795</td>
<td>APACHE II: 21.7 (both groups) PaO2/FIO2: 113 ± 38 (both groups)</td>
<td>HFOV: 2.2 ± 2.3 CMV: 2.2 ± 2.3</td>
<td>No significant difference in the number of days on which patients received inotropic agents or pressor infusions (2.8 ± 0.6 d in conventional ventilation group vs. 2.9 ± 4.5 d in HFOV group)</td>
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</table>

TABLE 107.3 Characteristics of OSCAR and OSCILLATE Trials Study Design and Methodology

<table>
<thead>
<tr>
<th>Study design</th>
<th>OSCAR</th>
<th>OSCILLATE</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study design</td>
<td>Multicenter randomized control trial 29 ICUs in the UK 795 patients (HFOV: 398, CMV: 397)</td>
<td>Multicenter randomized control trial 39 ICUs in several countries, mainly North America 548 patients (HFOV: 275, CMV: 273)</td>
<td>The OSCILLATE trial planned to recruit 1200 patients but was terminated early. Most of OSCILLATE trial centers are experienced with HFOV use in OSCAR trial; only 9 centers had previous experience with HFOV. Baseline characteristics were similar in both studies except for APACHE II score and time of calculation</td>
</tr>
<tr>
<td>Ventilatory strategy</td>
<td><strong>HFOV arm</strong></td>
<td>The initial settings were a ventilation frequency of 10 Hz, an mPaw of 5 cm H2O above the Pplat of CMV at enrollment. Hypoxemia was treated by increasing the mPaw and then by increasing the FIO2 level. Titration of FIO2 as first step before reducing mPaw in the weaning process.</td>
<td>Initial mPaw value was 30 cm H2O (highest value allowed 38 cm H2O). Further titration is based on a strict protocol.</td>
</tr>
<tr>
<td><strong>CMV arm</strong></td>
<td>According to local practice in the participating ICUs. However, encouraged to use pressure-controlled ventilation targeting a tidal volume of 6 to 8 ml/kg of PBW, and to use the combinations of PEEP and FIO2 values that were used in the ARDS Network study.</td>
<td>Adhered to a strict protocol of target Vt of 6 ml/kg PBW or less and PEEP of 35 cm H2O or less, PEEP levels were high, based on modified previously published PEEP/FIO2 tables.</td>
<td>The result is higher tidal volumes (8.3 ± 2.9 ml/kg PBW vs. 6.1 ± 1.3 ml/kg PBW) and lower PEEP levels (11.4 ± 3.6 cm H2O vs. 18 ± 3.0 cm H2O in the OSCAR trial than OSCILLATE trial.</td>
</tr>
<tr>
<td>Recruitment maneuver</td>
<td>Recruitment maneuvers were not mandated in either arm</td>
<td>Recruitment maneuvers (sustained inflation of 40 cm H2O for 40 s) were performed repeatedly.</td>
<td></td>
</tr>
</tbody>
</table>

pPa, plateau pressure; mPaw, mean airway pressure; CMV, controlled mechanical ventilation; HFOV, high-frequency oscillatory ventilation; PEEP, positive end-inspiratory pressure; PBW, predicted body weight.
The difference in the outcomes of the two studies can be attributed to multiple factors. The most significant is the ventilatory management of both arms. The adherence to the low-tidal volume strategy in OSCILLATE trial could contribute to the lower mortality rate in the control group in comparison to the OSCAR trial (35% vs. 48%). In addition, the early termination of the OSCILATE trial might have exaggerated the harm of HFOV. As to why neither trial was able to show a beneficial effect of HFOV despite much theoretical promise, this is also likely multifactorial. These factors include that the incremental increase in lung protective ventilation with HFOV may have been smaller than anticipated, and that adverse effects related to HFOV (e.g. need for more sedation, increased vasopressor requirements, effects of higher mean airway pressures on the right heart) outweighed any potential benefit.

With the inclusion of the OSCILLATE and OSCAR trials result, a meta-analysis (97) analyzed six RCTs comparing HFOV to CMV in early moderate-to-severe ARDS. The majority of patients (84%) were from OSCAR and OSCILATE trials. Compared with conventional mechanical ventilation, HFOV did not significantly reduce the mortality at 28 or 30 days (pooled relative risk was 1.051 (95% CI: 0.813 to 1.358)). This study concluded that HFOV should not be utilized as a mode of mechanical ventilation in patients with early moderate-to-severe ARDS due to lack of mortality benefit in comparison to low tidal volume, high PEEP mechanical ventilation, and a possible trend toward higher mortality. These results should not necessarily be extended to the use of HFOV as a rescue therapy in patients with refractory hypoxemia as none of the included studies evaluated that indication.

### COMPLICATIONS

In comparison to controlled mechanical ventilation, patients ventilated with HFOV require more vasoactive medications. This hemodynamic effect could be attributed to high mean airway pressures increasing right ventricular afterload or reducing venous return and the negative effect on left ventricle performance at the presence of low filling pressures (98–100). It also could be attributed to the higher doses of sedatives used for HFOV patients (94,95,101). Adequate sedation and analgesia during HFOV in necessary to ensure patient–ventilator synchrony. The incidence of barotrauma in patients ventilated by HFOV did not differ from those ventilated with controlled mechanical ventilation (92,93,97,102).

### FUTURE DIRECTIONS

Research in the field of the ventilatory care of ARDS patients and the prevention of VILI has been the focus of many investigators in critical care. Despite the physiologic rationale and encouraging initial data, the outcome of the use of HFOV has been disappointing. Patients with mild disease and nonrecruting lung are likely not good candidates for HFOV as increasing mean airway pressure that may lead to overdistention of some lung regions without increased aeration of collapsed or flooded alveoli worsened alveolar stress and strain (103).

We believe that HFOV should not be used routinely in adults with ARDS. Future clinical use and studies should be tailored to include targeted patient populations. ARDS patients who might benefit from what HFOV has to offer include those with severe ARDS and important hypoxemia despite lung-protective lung ventilation utilizing high PEEP and other evidence-based adjuvant therapies such as prone positioning and paralysis (78,104,105) as a “rescue” therapy. In addition, dynamic assessment of a patient's response to HFOV may be useful. In a retrospective study, patients with improved oxygenation following HFOV, which is a surrogate of recruitability, seemed to benefit more from HFOV (91).

### CONCLUSION

In summary, HFOV should not be recommended for routine use in adults with ARDS because of a lack of survival benefit with the application of HFOV and possibly trend toward harm. HFOV might be considered as a “rescue therapy” in patients who have failed lung-protective low tidal volume conventional mechanical ventilation after the utilization of more supported therapeutic intervention, such as higher PEEP (78), neuromuscular blockade (104), and prone positioning (105).

### Key Points

- HFV modes are characterized by generation of very low tidal volumes at high frequencies and HFOV is the most commonly used mode.
- Ventilator-induced lung injury may worsen lung injury in patients with ARDS and induce multiple organ dysfunction through multiple mechanisms. Ventilator strategies should avoid volutrauma by using low tidal volumes, and avoid atelectrauma and oxygen toxicity through lung recruitment.
- HVOC does not reduce mortality in comparison to low tidal volume conventional mechanical ventilation utilizing high PEEP in patients with early moderate-to-severe ARDS, and therefore should not be used routinely in this population.
- HFOV might be used as a rescue mode of ventilation in patients with severe respiratory failure when oxygenation is not achievable by optimal low tidal volume and high PEEP-controlled mechanical ventilation and the application of evidence-based adjuvant therapy such as prone positioning.

### References


