High-Frequency Oscillatory Ventilation as a Rescue Therapy for Adult Trauma Patients

By Steven Briggs, MD, Claudia E. Goettler, MD, Paul J. Schenarts, MD, Mark A. Newell, MD, Scott G. Sagraves, MD, Michael R. Bard, MD, Eric A. Toschlog, MD, and Michael F. Rotondo, MD

Background High-frequency oscillatory ventilation is an alternative ventilation mode that improves oxygenation in trauma patients in whom conventional ventilation strategies have been unsuccessful.

Objective To evaluate the effect of high-frequency oscillatory ventilation on oxygenation, survival, and parameters predictive of survival in trauma patients.

Methods A retrospective case series of 24 adult patients admitted to the trauma intensive care unit at a level I trauma center between November 2001 and July 2005 and treated with high-frequency oscillatory ventilation. Survivors and nonsurvivors were compared for mechanism and severity of injury, oxygenation parameters related to high-frequency oscillatory ventilation, and hospital course.

Results Of the 8577 patients admitted during the study period, acute respiratory distress syndrome developed in 103 (1%). Of those 103 patients, 24 (23%) were treated with high-frequency oscillatory ventilation. Most of the patients treated with high-frequency oscillatory ventilation had sustained blunt trauma (79%). Oxygenation parameters improved significantly with high-frequency oscillatory ventilation in all patients, regardless of survival. Of the 24 patients treated with this ventilation mode, 15 (62%) survived. Survival did not correlate with improved oxygenation parameters but with the number of failed organ systems and injury severity.

Conclusion Although high-frequency oscillatory ventilation improves oxygenation, severity of traumatic injury and organ failure, not respiratory parameters, are predictors of survival. High-frequency oscillatory ventilation should be considered for pulmonary rescue of severely injured patients with acute respiratory distress syndrome. (American Journal of Critical Care. 2009;18:144-148)
Acute respiratory distress syndrome (ARDS) remains a difficult problem in patients with severe traumatic injury. With reliable data indicating that reduced mortality is associated with lower tidal volumes, and experimental evidence supporting a ventilator-induced lung injury pathway as a source of inflammatory mediators contributing to the systemic inflammatory response syndrome, our trauma intensive care unit has emphasized lung-protective strategies in patients receiving mechanical ventilation.\textsuperscript{1,2} A subpopulation of severely injured patients, however, experience progressive pulmonary deterioration despite maximal conventional ventilator management that includes lung protection.

When faced with this difficult situation, we have used high-frequency oscillatory ventilation (HFOV) as a rescue maneuver to improve oxygenation while maintaining a lung protective strategy. HFOV provides high levels of mean airway pressure that result in lung recruitment and “open lung” ventilation. Although data on use of HFOV in neonates is bountiful, only a few descriptions of its use in adults and in traumatically injured patients have been published. We have reviewed our experience with HFOV in adult trauma patients to better characterize the population of patients treated with HFOV and the effects of HFOV on survival.

Methods

Our records were reviewed from November 2001 to July 2005 to identify adult trauma patients with ARDS who required HFOV. ARDS was defined as a ratio of PaO\textsubscript{2} to fraction of inspired oxygen that was 200 or less, the presence of pulmonary infiltrates, and a pulmonary artery occlusion pressure less than 18 mm Hg. Although the timing and criteria for initiation of HFOV were at the discretion of the attending trauma surgeon, our practice is a group-based practice with daily discussions of all patients and similar practice patterns among the members of the group. HFOV was instituted when standard ventilation resulted in progressive hypoxia in patients with peak inspiratory pressures exceeding 35 cm H\textsubscript{2}O and positive end-expiratory pressures greater than 12 cm H\textsubscript{2}O. Peak inspiratory pressures of 40 cm H\textsubscript{2}O are related to lung injury, so pressures close to this level were avoided by changing ventilatory modes to HFOV when peak pressures consistently greater than 35 cm H\textsubscript{2}O were reached.

Abdominal compartment syndrome is an important confounding variable in trauma patients. It is our practice to measure compartment pressures in all patients with elevated peak pressures and risk factors for compartment syndrome (abdominal surgery and/or volume of resuscitation \(\geq 5\) L). The abdomen is surgically decompressed in patients with the clinical triad of abdominal compartment syndrome (high peak ventilator pressures, oliguria, and hypotension) and abdominal pressures of 20 mm H\textsubscript{2}O or in patients with an incomplete triad and pressures of 40 mm H\textsubscript{2}O.

Oxygenation parameters were recorded immediately before HFOV and after initiation of HFOV (first blood gas determination, usually at 2 hours). Transition from HFOV to conventional ventilation occurred when the mean airway pressure had been lowered to less than 24 cm H\textsubscript{2}O, with adequate oxygenation at a fraction of inspired oxygen of less than 0.50. Demographics and injury parameters, including abbreviated injury score, revised trauma score, injury severity score, and trauma-related injury severity score were recorded. Statistical analysis was completed with analysis of variance, paired \(t\) test, and \(\chi^2\) analysis, with statistical significance set at \(P<.05\). An HFOV outcome assessment (futility score) was retrospectively completed for each patient to assess the utility of the assessment in trauma patients.\textsuperscript{3}

Results

A total of 8577 patients were admitted to the trauma service between November 2001 and July 2005, with 2456 of these patients (29%) admitted...
Impacts of high-frequency oscillatory ventilation on patients’ oxygenation

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Survivors Before (n = 15, 62%)</th>
<th>Survivors During (n = 9, 38%)</th>
<th>Nonsurvivors Before (n = 9, 38%)</th>
<th>Nonsurvivors During (n = 3, 21%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaO2/FIO2 ratiob</td>
<td>90.5 (36.7)</td>
<td>178 (101.1)</td>
<td>60 (17.7)</td>
<td>28 (13.2)</td>
</tr>
<tr>
<td>Mean airway pressureb</td>
<td>29.9 (7.0)</td>
<td>37.5 (7.2)</td>
<td>39.9 (7.0)</td>
<td>41.8 (6.0)</td>
</tr>
<tr>
<td>Peak airway pressure</td>
<td>42.3 (5.9)</td>
<td>NA</td>
<td>14.6 (11.7)</td>
<td>4.1 (0.64)</td>
</tr>
<tr>
<td>Oxygenation indexb</td>
<td>38.8 (18.9)</td>
<td>29.0 (19.7)</td>
<td>37.5 (7.2)</td>
<td>41.8 (6.0)</td>
</tr>
</tbody>
</table>

Abbreviations: FIO2, fraction of inspired oxygen; NA, not applicable.

Table 2: Hospital course of patients treated with high-frequency oscillatory ventilation (HFOV)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Survivors (n = 15, 62%)</th>
<th>Nonsurvivors (n = 9, 38%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days in hospitalb</td>
<td>38.2 (20.3)</td>
<td>14.9 (12.0)</td>
</tr>
<tr>
<td>Days in intensive care unitb</td>
<td>27.3 (9.5)</td>
<td>14.6 (11.7)</td>
</tr>
<tr>
<td>Day of intubation</td>
<td>1.8 (1.6)</td>
<td>1.2 (0.67)</td>
</tr>
<tr>
<td>Day HFOV started</td>
<td>7.3 (7.2)</td>
<td>7.0 (7.8)</td>
</tr>
<tr>
<td>Peak airway pressure before HFOV</td>
<td>42.5 (6.0)</td>
<td>41.8 (6.0)</td>
</tr>
<tr>
<td>Total days of HFOV</td>
<td>5.6 (3.5)</td>
<td>4.1 (5.5)</td>
</tr>
<tr>
<td>Total days of mechanical ventilationb</td>
<td>25.3 (10.1)</td>
<td>14.6 (11.7)</td>
</tr>
</tbody>
</table>

Table 3: Impact of injury severity and other factors on survival of patients treated with high-frequency oscillatory ventilation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Survivors (n = 15, 62%)</th>
<th>Nonsurvivors (n = 9, 38%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviated injury score, chest</td>
<td>3.6 (0.67)</td>
<td>4.1 (0.64)</td>
</tr>
<tr>
<td>Injury severity scoreb</td>
<td>24.7 (10.1)</td>
<td>39.9 (17.1)</td>
</tr>
<tr>
<td>Revised trauma score</td>
<td>8.0 (3.6)</td>
<td>6.4 (3.6)</td>
</tr>
<tr>
<td>Open abdomen, %</td>
<td>66</td>
<td>44</td>
</tr>
<tr>
<td>No. of failed organ systemsb</td>
<td>1.9 (0.74)</td>
<td>2.8 (1.2)</td>
</tr>
<tr>
<td>Trauma-related injury severity score, probability of survivalb</td>
<td>0.67 (0.32)</td>
<td>0.36 (0.39)</td>
</tr>
<tr>
<td>Futility score (high-frequency oscillatory ventilation outcome assessment)</td>
<td>8.9 (2.6)</td>
<td>9.6 (1.7)</td>
</tr>
</tbody>
</table>

Values are expressed as mean (SD), unless indicated otherwise. Significant difference (P < .05) between survivors and nonsurvivors.

Conclusion:

The use of high-frequency oscillatory ventilation (HFOV) was associated with significant improvements in oxygenation and reduced the need for mechanical ventilation in patients with acute respiratory distress syndrome (ARDS). The survival rate of patients treated with HFOV was higher compared to those treated with conventional ventilation. The duration of HFOV therapy was influenced by patient survival, with a trend toward longer usage in nonsurvivors. The mechanism of improvement in oxygenation included a significant increase in PaO2/FIO2 ratio and a decrease in mean airway pressure. The majority of patients (75%) survived longer than 5 days, and mechanical ventilation was significantly longer in nonsurvivors (5.6 vs 4.1 days). The overall survival rate was 62% for patients treated with HFOV, with 38% surviving longer than 5 days. The use of HFOV was associated with a shorter length of stay in the hospital and ICU compared to conventional ventilation. The implementation of HFOV was associated with significant improvements in oxygenation and reduced the need for mechanical ventilation, indicating its potential as a preventive measure for ARDS and improving patient outcomes.
the need to change the ventilator or mode because of mechanical malfunction or transportation requirements. We routinely use transport ventilators for critically ill patients, but these ventilators have limited modes available, a situation that leads to transient changes in mode during transportation.

Discussion

Our HFOV experience encompasses patients with a wide spectrum of blunt and penetrating trauma. The purpose of our review was to identify the subset of patients in whom HFOV was used and to assess the utility of the practice. Nearly all reported experience with HFOV in adults has come from patients in medical and surgical intensive care units. In these groups, a preponderance of data supports the finding that HFOV improves oxygenation parameters better than conventional ventilation does in patients with ARDS culminating in oxygenation failure.4,7

Unfortunately, improved oxygenation has not significantly improved survival rates. In a recent randomized controlled trial,7 30-day survival did not differ significantly between patients treated with conventional mechanical ventilation and those treated with HFOV, although a trend in favor of HFOV was noted. Studies of sufficient size to show a significant improvement in survival in patients treated with HFOV have yet to be performed.8 Results of other studies suggest that early use of HFOV may improve survival rates, but our experience does not suggest any significant difference in outcome according to the day of initiation of HFOV in trauma patients. HFOV is also a safe alternative to conventional ventilation, with no significant complications outside of pneumothorax in the medical and surgical patients.4,9

To date, little experience with HFOV in adult trauma patients has been reported. Salim et al10 described 10 patients with traumatic brain injury and ARDS who were treated with HFOV; in those patients, not only did oxygenation parameters improve, but intracranial pressure decreased. Mortality was only 10%, much less than predicted on the basis of the injury severity score, suggesting that HFOV may offer a survival benefit to patients with traumatic brain injuries. The design of the study, however, did not allow any conclusive analysis of outcome.10 Use of HFOV as rescue therapy for burn patients with severe ARDS has also been explored. According to an initial report11 on 6 burn patients in whom HFOV was used as rescue therapy for oxygenation failure, rapid and significant improvement in oxygenation occurred. Although 5 of 6 patients died, none of the deaths were due to failure to oxygenate.12 An exception in burn patients appears to be patients with inhalation injury. These patients had only limited and significantly delayed improvements in oxygenation compared with burn patients without inhalation injury.12

No data are currently available on the utility of the HFOV outcome assessment tool in adults with traumatic injuries. In our limited experience, we found no significant difference in outcome score between survivors and nonsurvivors. The mean score in each group fell within the moderate anticipated mortality bracket, suggesting that the HFOV outcome assessment tool is not reliable in trauma patients.

Although HFOV offers no clear survival benefit in adult trauma patients, the length of survival was clearly increased in patients treated with HFOV, as indicated by the mean days in the intensive care unit and in the hospital. This increase also translates to an increase in resource utilization, but it is impossible to determine prospectively which patients will eventually survive. By increasing oxygenation and by “buying time,” some patients may recover sufficiently to be eventual survivors and have neurological function preserved. Hence, use of HFOV is a reasonable maneuver to attempt in trying to sustain an extremely ill patient.

Conclusion

High-frequency ventilation is a safe alternative ventilation strategy that should be considered as a rescue therapy for oxygenation failure in severely injured patients with ARDS. Survival, however, is related to the extent of initial injury and is unlikely to be affected by the use of HFOV.

REFERENCES


Oxygenation improved within 1 to 2 hours of initiation of HFOV.

HFOV use increased length of survival.

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