Management of Malignant Air Leak in a Child with a Neonatal High-Frequency Oscillatory Ventilator

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A 10-year-old, 36-kg child with a malignant air leak who failed conventional mechanical ventilation and high-frequency jet ventilation was successfully treated with a neonatal high-frequency oscillatory ventilator for 31 days. Since the air leak resolved with minimal hemodynamic compromise, this technique may have application in the management of respiratory failure and air leak in the older and larger child for prolonged periods of time.

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HFJV = high-frequency jet ventilation; HFOV = high-frequency oscillatory ventilation; CV = conventional ventilation; IRB = institutional review board

High-frequency jet ventilation (HFJV) has been shown to be beneficial in treatment of respiratory failure associated with air leak in adults¹ and neonates.¹ In addition, high-frequency oscillatory ventilation (HFOV) has been found effective in treatment of pulmonary interstitial emphysema in neonates.² We report the continued use of neonatal HFOV in the management of malignant air leak in a 36-kg child for 31 days.

CASE REPORT

A 10-year-old, 36-kg male with an acquired T-cell defect* (human immunodeficiency virus serology negative) presented with hepatosplenomegaly, pneumonia, clinical varicella, and pleural effusion. Initial culture grew Escherichia coli and nontypeable α-streptococcus from pleural fluid and Streplococcus pneumoniae from blood. By the third hospital day, he was intubated and placed on conventional ventilation (CV) for respiratory failure. Bronchoscopy revealed endobronchial varicella-like lesions and cultures grew Streplococcus caris and Staphylococcus aureus. Viral culture grew Salmonella serotype C2.

Antimicrobial therapy included acyclovir, varicella-zoster immune globulin, vancomycin, amikacin, ticarcillin-clavulanic acid, and trimethoprim-sulfa. Ventilatory support was escalated to a positive end-expiratory pressure (PEEP) of 19 cm H₂O and FIO₂ of 0.60 without the development of air leak or hemodynamic dysfunction. Over the first two weeks his pneumonia improved, but on day 15, residual bronchiectasis and abscess formation was treated with drainage by right thoracotomy. On day 19, right-sided air leak developed; he was taken to the operating room for a right upper and middle lobectomy. Postoperatively, a right bronchopleural fistula developed.

After permission from our institutional review board (IRB) for human experimentation and informed parental consent, HFJV was attempted on day 22. After 15 hours, because of failure to oxygenate or ventilate (Pao₂, 43 mm Hg; pH, 7.38; Pco₂, 84 mm Hg), CV was resumed (PEEP, 20 cm H₂O; Fio₂, 0.80).

With the persistence of air leak on hospital day 24, again receiving IRB permission and parental consent, a neonatal high-frequency oscillatory ventilator (SensorMedics 3100) was obtained on a compassionate basis. Initial settings were a mean airway pressure (Paw) of 32 cm H₂O, Fio₂ of 1.0, flow of 12 L/min, frequency of 12 Hz (730 cycles per min), delta P (proximal airway phasic pressure difference) of 56 cm H₂O, and power of 4.3. (The power control is a ten turn knob (maximum of 10 equals approximately 30 W) and is the power applied to a linear motor that drives a diaphragm-sealed piston). Oxygenation was equal to that of CV on PEEP of 22 cm H₂O (Paw, 30 cm H₂O). Figure 1 shows oxygenation on the various forms of ventilation as measured by the arteriolar/alveolar oxygen index.

By day 13 of oscillation, the Paw was weaned to 20 cm H₂O and

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Figure 1. Oxygenation defined by the arteriolar/alveolar oxygen index is shown on conventional ventilation (CV), jet ventilation (JV), and high-frequency oscillation (HFO) at initiation of HFO and days 1, 12, 16, and 26 of HFO.

Figure 2. The cardiac index is shown on conventional ventilation (CV) and high-frequency oscillation (HFO) at initiation, 8 hours, and 1, 16, and 20 days.

CHEST / 100 / 1 / JULY, 1991
leak was 2 to 4 L/min. On day 14 of oscillation, the patient developed a *Pseudomonas aeruginosa* pneumonia and required increase in Paw to 32 cm H₂O with no change in air leak. By day 20 of oscillation, mean pressure was 22 cm H₂O and the leak sealed.

On day 30 of oscillation, the patient had a recurrence of a *Pseudomonas aeruginosa* pneumonia that responded to antibiotic therapy and increased oxygen. On day 31, an internal hemothorax was noted and the patient tolerated the resumption of CV. A subsequent *Candida albicans* empyema responded to amphotericin B and right-sided tube thoracostomy. He was discharged home on hospital day 180 with Fio₂ of 0.28 oxygen via a tracheotomy collar. Bronchoscopy at time of tracheostomy showed no tracheal injury. Attempts at pulmonary function testing have been unsuccessful due to lack of patient cooperation, but the patient has had his tracheostomy decannulated and has been weaned to Fio₂ of 0.21 with oxygen saturation of 95 percent at 12 months follow-up.

**DISCUSSION**

We have demonstrated that the older (10 years) and larger (36-kg) child with respiratory failure and air leak refractory to CV or HFJV can be treated with neonatal HFOV. Because of risk of barotrauma and subsequent chronic lung disease secondary to the large phasic swings of the conventional ventilator cycle, high-frequency ventilation (HFV) appears to be an attractive alternative. A unique characteristic of HFV is the reduction of the phasic pressure differential because of dampening of the pressure wave across the endotracheal tube and also because of reduction of the pressure amplitude as airway diameter decreases in distal bronchial generations. HFJV has been used successfully to manage pulmonary edema and respiratory failure complicated by air leak in adults. Another theoretic advantage of HFJV and/or HFOV may be less hemodynamic compromise than seen with high PEEP. Our patient had improved CI after initiation of oscillation. The neonatal experience with HFJV as a rescue technique has been complicated by tracheal injury. HFOV is reported to have a lower incidence of tracheal injury than HFJV, and in our patient, no tracheal injury was found.

The technique of HFOV in which small tidal volumes are delivered at frequencies of 4 to 15 Hz has been used successfully to ventilate neonates with pulmonary interstitial emphysema for periods of one to 30 days. Additional reports have used HFOV (1 to 14 days) for refractory respiratory failure meeting the criteria for neonatal extracorporeal membrane oxygenation and with a variety of neonatal lung disease, including hyaline membrane disease (1 to 8 days). The multicenter controlled trial of HFOV compared with CV showed no advantage of oscillation in the treatment of respiratory failure in the preterm infant. The authors found an increased incidence of grade 3 and 4 intraventricular hemorrhage, periventricular leukomalacia, and pneumoperitoneum; and while the authors did not report the length of use of HFOV in their study group, all patients in the HFOV group remained on HFOV until extubation or crossover. In adult patients, HFOV has been studied in patients after vascular surgery or for treatment of respiratory failure (duration up to 1 h) and intraoperatively (no duration specified). The application of this technique in the pediatric age group, as in the adult population, has been limited by the lack of ventilators with sufficient power to generate the tidal volume necessary to ventilate the larger child and by lack of documentation of prolonged use.

Given our success in treatment of this child and the need for an alternative ventilator in the group of children intolerant of CV because of air leak or hemodynamic compromise, a randomized controlled trial of HFOV in the older and larger child is indicated. Intraventricular hemorrhage and periventricular leukomalacia are age dependent and not encountered in the older child. Furthermore, a controlled trial of oscillation of children would allow careful study of HFOV before devices such as these are available for other indications (hyaline membrane disease) and its use could be extended to the pediatric population in an uncontrolled rescue fashion. In addition, studies need to be done to further the understanding of this technique in the larger thorax.

**REFERENCES**