High-frequency percussive ventilation in a pediatric patient with hydrocarbon aspiration

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Introduction: To describe ventilator management using a high-frequency percussive ventilator (HFPV), after other modes of mechanical ventilation failed.

Design: Case series.

Setting: Pediatric intensive care unit.

Patients: Previously healthy 11-month-old male with severe aspiration pneumonitis from mineral oil.

Interventions: The patient was initially placed on a conventional ventilator in a pressure-regulated volume-control mode but needed higher-than-normal pressures to maintain adequate ventilation. A decision was made to switch the patient to a pressure-control/pressure-support mode. At the end of the third day of pressure-control/pressure-support mode, a decision was made to attempt airway pressure-release ventilation. During a trial attempt, saturation levels deteriorated and a decision was made to place the patient on a high-frequency oscillator. The patient remained on this mode of ventilation for 6 days. On the sixth day, the chest radiograph showed a worsening of his pneumonia, and the patient started to deteriorate. A decision was made to try the HFPV in an attempt to mobilize secretions and any residual mineral oil. Immediately after initiating the HFPV and for 4 hrs thereafter, large amounts of secretions—including a thick, oily substance—were suctioned from the airways. Within 12–24 hrs, oxygenation improved dramatically and F_{IO_2} was weaned. During the next 12 hrs, the patient was weaned off HFPV onto a conventional ventilator, and he was extubated 48 hrs after initiating HFPV.

Conclusions: In this case, HFPV used as an alternative mode of ventilation successfully mobilized secretions that were otherwise unobtainable and that we believe led to the swift recovery of this child. HFPV should be given consideration as a mode of ventilation when mobilization of secretions is an issue. (Pediatr Crit Care Med 2007; 8:383–385)

Mineral oil is a common remedy to treat chronic constipation in the pediatric population. Ingestion of mineral oil by infants and children may not always evoke a protective cough reflex, and ultimately, aspiration can occur. Aspiration of hydrocarbons (mineral oil) can result in severe pneumonitis, and in cases of chronic aspiration, it can over time lead to lipoid pneumonia. Pulmonary symptoms from hydrocarbon aspiration range from minimal injury to severe acute respiratory distress syndrome from pneumonitis. We describe the ventilator management of a previously healthy 11-month-old male with severe aspiration pneumonitis from mineral oil using a high-frequency percussive ventilator (HFPV), after other modes of mechanical ventilation failed to improve the status of the child. The University of North Carolina School of Medicine Institutional Review Board approved this case report study.

CASE REPORT

A previously healthy 11-month-old, 10-kg male ingested an unknown amount of mineral oil and was taken from his home to a nearby hospital. He presented to the outside hospital with cyanosis and lethargy and was intubated and transferred to the pediatric intensive care unit at our institution for further management of his respiratory failure.

Initially, the patient was placed on a conventional ventilator in a pressure-regulated volume-control mode for approximately 1 hr, but he needed higher-than-normal pressures to maintain adequate ventilation. A decision was made to switch the patient to a pressure-control/pressure-support mode on a Servo-i ventilator (Siemens, Danvers, MA) with pressure support ventilation 10, positive inspiratory pressure 28–32, positive end-expiratory pressure 8, and F_{IO_2} 50% to 80%. Arterial blood gases on these settings were pH 7.16–7.21, P_{CO_2} 46–62, and P_{aO_2} 60–120. At the end of the third day on pressure-control/pressure-support mode, a decision was made to attempt airway pressure-release ventilation because of worsening hypoxemia. During an initial 1-hr trial of airway pressure-release ventilation, oxygen saturation levels deteriorated to low levels and a decision was made to place the patient on the Sensormedics 3100A (Viasys, Conshohocken, PA) high-frequency oscillator (HFO). The HFO settings were 8 Hz, amplitude 40–48, mean arterial pressure 25–28, and F_{IO_2} 50% to 100%. The patient remained on this mode of ventilation for 6 days, with arterial blood gases pH 7.38 (±0.5), P_{CO_2} 50–60, and P_{aO_2} 57–100. On the sixth day of HFO, a chest

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radiograph was obtained that showed a worsening of his pneumonia but without acute respiratory distress syndrome. The patient did not have signs of septicemia during his intensive care admission. Pharmacologic interventions included vancomycin, ceftriaxone, and azithromycin. On intensive care day 3, fiberoptic bronchoscopy revealed severe mucous plugging. A significant amount of secretions were removed at that time. However, the patient started to deteriorate, with oxygen saturations in the low 80s. A decision was made to try the HFPV (VDR-4, Percussionaire, Sandpoint, ID) in an attempt to mobilize secretions and any residual mineral oil. Initial settings on the HFPV were a positive inspiratory pressure 26, positive end-expiratory pressure 8, phase rate 20, percussive rate 600, inspiratory time 2.5 secs, and FIO_2 100%.

Immediately after initiating the HFPV and for 4 hrs thereafter, large amounts of secretions—including a thick, oily substance—were suctioned from the airways. Within 12–24 hrs, oxygenation improved dramatically (Tables 1 and 2), and FIO_2 was weaned to 35%. During the next 12 hrs, the patient was weaned off the HFPV onto a conventional ventilator with a volume-support mode, and he was successfully extubated 48 hrs after initiating HFPV.

DISCUSSION

HFPV delivers subtidal volumes superimposed onto conventional-type breaths. The subtidal volumes are small, pulsed, percussive breaths, which provide for effective mobilization of secretions, making it ideal for patients with large amounts of secretions and inhalation injuries. The rate of subtidal volumes is normally set between 400 and 700 breaths per minute, and they are stacked on top of one another in a stepwise fashion, forming what is analogous to a conventional ventilator breath. Each subtidal volume is estimated to be 50–60 mL. Short expiratory times can be set to allow for automatic positive end-expiratory pressure to occur and exhalation is active. HFPV is engineered to provide for oxygenation and CO_2 elimination using lung-protective strategies by using lower peak inspiratory pressures, while maintaining adequate mean airway pressures. A typical breath waveform is depicted in Figure 1.

In 1989, Cioffi and colleagues (1) were the first to describe HFPV as a mode of ventilation in burn patients with severe inhalation injury. The group observed improvements in survival rates and a decrease in pneumonias in adult patients with inhalation injuries who were placed on HFPV.

Positive results also have been observed in the pediatric population. Cortiella and colleagues (2) studied 13 pediatric patients ranging in age from 6 to 9 yrs, all with inhalation injuries. The group found that patients treated with HFPV had no cases of pneumonia, had better PaO_2/FIO_2 ratios and lower peak inspiratory pressures, and had less work of breathing in comparison with control groups. Carman and colleagues (3) from the Shriners Burn Hospital in Cincinnati randomized 64 pediatric patients with inhalation injuries to either pressure-controlled ventilation or HFPV using the VDR-4 ventilator. The group found that those patients who were ventilated with HFPV used significantly lower peak airway pressures and had significantly higher PaO_2/FIO_2 ratios. They concluded that the VDR-4 was safe for pediatric patients and was a good alternative to conventional ventilators.

HFPV also has been shown in a small number of studies to have a positive impact on patients with acute respiratory distress syndrome who were failing conventional ventilation. Velmahos and colleagues (4) studied 32 consecutive patients with acute respiratory distress syndrome that were placed on HFPV and compared HFPV parameters with the patients' conventional ventilation parameters. The parameters that were analyzed were mean airway pressures, peak inspiratory pressures, and PaO_2/FIO_2 ratios. They found that HFPV improves oxygenation by increasing mean airway pressures, and this was done with lower peak inspiratory pressures compared with conventional ventilation. They also noted that hemodynamics in patients on HFPV were not affected by this mode of ventilation.

Table 1. Ventilator settings on high-frequency oscillation (HFO) showing arterial blood gases (ABGs) before placement on high-frequency percussive ventilation (HFPV) and ventilator settings on HFPV with ABGs showing improvement in oxygenation

	pH	$PaCO_2$	PaO_2	HCO_3^-	SaO_2
HFO settings					
MAP 25, AMP 40, Hz 8, FIO_2 100%	7.38	50	57	30	91
MAP 28, AMP 48, Hz 8, FIO_2 100%	7.22	89	63	26	92
HFPV settings					
PIP 26, PEEP 8, phase rate 20, percussive rate 600, I-time 2.5, FIO_2 100%	7.53	33	58	29	94
PIP 26, PEEP 10, phase rate 12, percussive rate 600, I-time 2.5, FIO_2 65%	7.38	50	206	27	99
PIP 24, PEEP 8, phase rate 12, percussive rate 600, I-time 2.5, FIO_2 40%	7.45	45	122	27	99

MAP, mean airway pressure; AMP, amplitude; PIP, positive inspiratory pressure; PEEP, positive end-expiratory pressure; I-time, inspiratory time.

Table 2. Oxygenation index and PaO_2/FIO_2 index on high-frequency oscillation (HFO) and high-frequency percussive ventilation (HFPV) settings

	Oxygenation Index	PaO_2/FIO_2 Ratio
HFO settings		
MAP 25, AMP 40, Hz 8, FIO_2 100%	40	57
MAP 28, AMP 48, Hz 8, FIO_2 100%	40	63
HFPV settings		
PIP 26, PEEP 8, phase rate 20, percussive rate 600, I-time 2.5, MAP 24, FIO_2 100%	40	58
PIP 26, PEEP 10, phase rate 12, percussive rate 600, I-time 2.5, MAP 28, FIO_2 65%	10	316
PIP 24, PEEP 8, phase rate 12, percussive rate 600, I-time 2.5, MAP 22, FIO_2 40%	10	305

MAP, mean airway pressure; AMP, amplitude; PIP, positive inspiratory pressure; PEEP, positive end-expiratory pressure; I-time, inspiratory time.

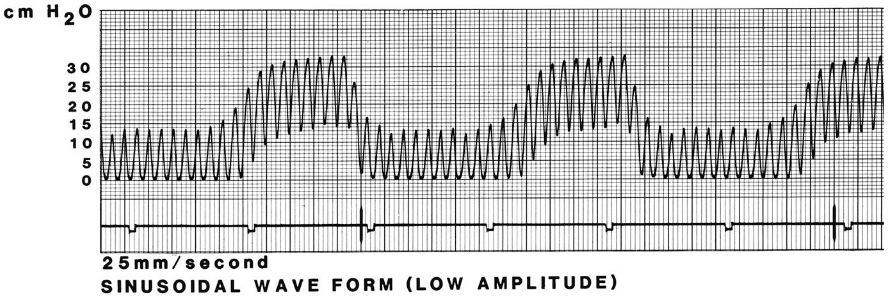

Figure 1. Waveform graph from the high-frequency percussive ventilator showing a sinusoidal wave form (low amplitude). Reproduced with permission from VDR-4 Users Manual. Sandpoint, ID, Percussionaire, 1993.

In a retrospective review, Salim and colleagues (5) concluded that in ten patients with acute respiratory distress syndrome resulting from severe traumatic brain injury, HFPV produced significant improvements in oxygenation, with concomitant reductions in intracranial pressure in the first 16 hrs of instituting this mode of ventilation. This study suggests that HFPV could be considered an optional mode of ventilation for patients with acute respiratory distress syndrome.

A case report by Lee and colleagues (6) describes two patients with hydrocarbon pneumonitis who were successfully managed using HFO or HFO with extracorporeal membrane oxygenation. In these two patients, HFO ultimately provided a successful means to ventilate and oxygenate a 15-month-old and a 17-yr-old patient. The authors were eventually successful using HFO and using HFO in conjunction with extracorporeal membrane oxygenation but required more days of ventilatory support. Our team felt that HFO was not working in our patient, and we had the ability to try HFPV. It enabled us to remove retained secretions more effectively, which rapidly improved oxygenation and Co_2 elimination in this child. This subsequently led to a shorter length of stay on the ventilator of 2 days. On day 3 of HFPV, we were able to extubate the patient.

Treatment of hydrocarbon aspiration with the use of HFO has been well documented; however, there are no reports of the use of HFPV with hydrocarbon aspiration. In this case, HFPV was an alternative mode of ventilation that was successful at secretion removal, oxygenation, and ventilation in this pediatric patient, and we believe the application of HFPV led to the patient's swift recovery. Further study of the possible expanded use of HFPV in clinical situations such as this may be warranted.

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