CASE REPORT

Is the use of high frequency oscillatory ventilator beneficial in managing severe chest injury with massive air leak?

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SUMMARY

Severe thoracic trauma can be associated with immediate life-threatening injuries including major air leak syndrome that can lead to acute respiratory failure and refractory hypoxaemia. Such injuries invariably require thoracotomy following failure of conventional ventilation strategy and paucity of other non-operative interventions. We describe a case in which we used high frequency oscillatory ventilation (HFOV) as a part of management of such injury and averted the need for thoracotomy.

BACKGROUND

Severe thoracic trauma in an adult patient can produce immediate life-threatening to potentially lethal injuries, varying from tension pneumothorax, flail chest, massive haemothorax, multiple pulmonary contusions, major air leak and tracheobronchial injury.¹ These invariably lead to acute respiratory failure and haemodynamic derangements. Yet, only a few of these injuries warrant thoracotomy. Most of them can be managed successfully non-operatively with ventilator support. A major air leak following chest injury might be associated with haemoptysis, subcutaneous emphysema and tension pneumothorax. Placement of a chest tube overcomes a large leak and expands the lung. However, failure of non-operative interventions to manage a persistent large leak leads to operative intervention. The role of high frequency oscillatory ventilation (HFOV) in such cases has not been sufficiently explored. We describe a case in which an operative intervention was obviated with use of HFOV following the failure of conventional methods.

CASE PRESENTATION

A 30-year-old man presented with a history of loss of consciousness and difficulty in breathing following a road traffic injury. Primary survey showed a potentially threatened airway with bilateral unequal air entry. He was hypoxic with alarmingly low oxygen saturation (SpO₂ 50%); tachycardic heart rate was 132 bpm with blood pressure of 130/90 mm Hg. His Glasgow Coma Scale was 13 (E3V4M6) with bilateral equally reacting pupils. Focused assessment sonography in trauma (FAST) scan was normal. Initial chest X-ray showed bilateral multiple rib fractures. He was immediately intubated and put on conventional ventilator. Intercostal drains were inserted bilaterally, which drained 400 mL of haemorrhagic fluid with air bubbles on

both sides. Subsequent contrast-enhanced CT depicted bilateral haemopneumothorax, left-sided gross subcutaneous emphysema, left collapsed lung with 2nd, 4th, 5th, 6th and 8th rib fractures and lung lacerations. His right-sided lung showed 4th, 5th, 6th, 7th and 10th rib fractures. Other associated injuries included laceration over the left parietal region, and bruises over the dorsum of his left hand and buttocks. He was immediately shifted to the intensive care unit (ICU; [figure 1](#)).

On arrival to the ICU, the patient was haemodynamically unstable with heart rate of 142 bpm, blood pressure 100/50 mm Hg and marked acidosis and hypoxia on arterial blood gas (ABG) analysis (pH 7.17, pCO₂ 51 mm Hg, PO₂ 54 mm Hg on FiO₂ 100%. Base excess of 9.9 mmol/L, lactate level 4 mmol/L). He was labelled as a case of severe acute respiratory distress syndrome (ARDS) (SaO₂ 77%) with bilateral lung contusions and lung lacerations.

Initial conventional ventilator modes on Ventilator (eXtend-Air Liquide) were tried for some time but they failed to improve oxygenation and ventilation. Volume control ventilation with the following settings: FiO₂ 100%, tidal volume 380 mL, respiratory rate 34 bpm, positive end expiratory pressure (PEEP) 8 cm H₂O, SO₂ 85% and pressure control ventilation: FiO₂ 100%, respiratory rate 28 bpm, PEEP 5 cm H₂O, pressure 20 cm H₂O did not show any benefit with further deterioration in haemodynamic and respiratory variables.

Promptly, HFOV (Sensormedics 3100 B) was initiated because of refractory hypoxaemia and failed conventional ventilation attempts. Initial Settings were targeted to achieve desired oxygenation and

Figure 1 CT scan depicts the presence of massive pneumothorax and subcutaneous emphysema, indicating presence of air leak.

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Figure 2 Initial chest X-ray showing the presence of pneumothorax and subcutaneous emphysema.

ventilation (power 6, FiO_2 100%, frequency 6.1 Hz, mean airway pressure 32.6 cm H_2O , Δp 34 cm H_2O). Repeated adjustments were made to the HFOV settings to optimise the respiratory parameters in accordance with frequent ABG analysis and chest X-rays. Once the patient stabilised, fractional inspired oxygen concentration (FiO_2) was titrated to 50% and mean airway pressures were reduced to 24.7 cm H_2O within 24 h. Sedatives and paralysing agents were administered for tolerance of HFOV. With the above intervention the volume output from the bilateral air leak decreased significantly with better oxygenation (figures 2 and 3).

After 30 h of HFOV, an attempt was made to liberate the patient as he fulfilled weaning criteria of HFOV liberation (FiO_2 50%, frequency 5.5 Hz, mean airway pressure 20.4 cm H_2O , SpO_2 saturation 98% with ABG values of pH 7.46, pCO_2 34 mm Hg, pO_2 59 mm Hg, lactate 1.1 mmol/L and SaO_2 92%). A trial of conventional ventilation was provided for a short duration. However, it was deemed a failure and led to further deterioration (PaO_2 53 mm Hg on 100% FiO_2).

HFOV was reapplied (frequency 6 Hz, amplitude 65 cm H_2O and mean airway pressure 26 cm H_2O). Over the next 3 days frequent alterations in settings were made to maximise the ventilation and control of the air leak. During this period, gradual reduction in FiO_2 (50%) was achieved with acceptable oxygenation (PO_2 80–100 mm Hg). The patient could maintain

Figure 3 Chest X-ray obtained after resolution of the air leak and stabilisation with HFOV.

oxygenation and ventilation with minimum frequency and mean airway pressures without producing an air leak (frequency 5 Hz and mean airway pressure 17.3 cm H_2O).

The patient was switched to conventional ventilation. Initially, respiratory parameters had brief fluctuations with a drop in oxygenation (PO_2 59 mm Hg), however, they recovered to 94 mm Hg within hours on 60% FiO_2 and PEEP of 5 cm H_2O . Ventilator and ABG parameters also improved over the next few days (table 1).

The clinical parameters were consistent with ABG's parameters and had sustained improvement. The patient was tracheostomised and weaned from respiratory support.

OUTCOME AND FOLLOW-UP

The patient was liberated from ventilation on the third post-tracheostomy day and discharged from the hospital 6 days following it. On follow-up of 6 months he is completely stable with normal functioning.

DISCUSSION

We report the successful use of HFOV in a case of bilateral air leak following thoracic injury that developed refractory hypoxaemia and ARDS. The early initiation of HFOV resulted in rapid control of the bilateral air leak and sustained improvements in oxygenation. The patient was eventually liberated from HFOV and put on conventional ventilation within a span of 6 days. Later, he was weaned and discharged home.

Thoracic injuries producing major air leak, lung collapse and bilateral pulmonary contusion, can be associated with severe ARDS and refractory hypoxaemia.¹ Hypoxaemia is multifactorial in such cases. The aetiology varies from direct to indirect factors. Such injuries are routinely managed with conventional treatment methods, for instance, chest drains, mechanical ventilation and supportive treatment. Failure of the conventional management strategy commonly leads to an operative intervention including thoracotomy.² Thoracotomy for managing a massive air leak following chest injury constitutes a major surgical decision, which has short-term and long-term implications for the patient.

The major problem in management of such injuries is treatment of severe hypoxaemia and achievement of adequate ventilation. Loss of volume through air leak and fistula compounds the problem. This invariably leads to failure to achieve adequate PEEP and treatment of severe hypoxaemia.

Following are strategies to manage such cases:

1. Conventional ventilation preferably pressure limit ventilation with high respiratory rate;
2. Use of double lumen tube with one lung ventilation;
3. Use of dual lung ventilation;
4. High frequency ventilation;
5. Extracorporeal ventilation.

Conventional ventilation with a pressure limit mode and high respiratory rate is the preferred option in the majority of cases. This mode helps in controlling the fistula leak and at the same time also maintains lower airway pressure.³ However, this needs to be monitored closely since the condition of the chest might further worsen, requiring interventions resulting in failure of the conventional ventilation mode.

A double lumen tube with one lung ventilation is possible if the disease is unilateral with contralateral normal lung. This isolates the abnormal lung and helps in preferential ventilation of the normal lung.

Dual lung ventilation or independent lung ventilation is a technique to ventilate both lungs independently from each

Table 1 Improvement in trends of ventilatory and arterial blood gas parameters

Day	Ventilator mode	FiO ₂ (%)	Mean airway pressure (cm H ₂ O)	PEEP/ Δ p (cm H ₂ O)	SO ₂ (%)	pH	PCO ₂ (mm Hg)	HCO ₃ (mmol/L)	Base excess (mmol/L)	Lactate (mmol/L)	PO ₂ (mm Hg)
Day 1	VCV	100	31.3	8	85	7.17	51	17.2	−9.9	4	77
	PCV	100	25	5	86	7.33	53	26.3	1.8		54
	HFOV	100	33.1	34	96	7.34	36	20.3	−5.8	3.5	92
		80	32.6	34	99	7.29	40	19.3	−6.9	3.8	84
		60	36.5	34	100	7.28	42	19.6	−6.7	2.9	91
Day 2		50	25.3	34	100	7.53	21	21.4	−4.6	2.6	98
	HFOV	60	24.9	47	98	7.46	34	25.2	0.4	1.1	92
		40	20.4	47	98	7.32	53	25.6	1	1	88
Day 3	HFOV	60	34	50	96	7.4	43	27.3	3.4	0.7	90
		40	34	50	92	7.44	39	26.7	2.2	0.6	83
		40	34	46	99	7.43	43	27.9	3.8	0.6	85
Day 4	HFOV	50	34	50	97	7.3	54	25	0.1	0.8	92
		45	34	46	99	7.35	51	26.7	2.3	0.5	96
Day 5	HFOV	50	17.3	35	100	7.37	48	26.6	2.1	0.4	100
Day 6	PSV	50	17(ppl)	7	94	7.43	43	27.8	3.8	0.8	91

HFOV, high frequency oscillatory ventilation; PCV, pressure control ventilation; PEEP, positive end expiratory pressure; PSV, pressure support ventilation; VCV, volume control ventilation.

other.⁴ However, this needs greater expertise and synchronisation of the ventilators.⁵

Extracorporeal ventilation helps in cases of refractory hypoxaemia not sufficiently managed with the aforementioned methods. However, the facility is available in very few centres. Gothner *et al*⁶ used extracorporeal membrane oxygenation in combination with high-frequency oscillatory ventilation in post-traumatic ARDS.

In our patient, as both lungs were affected, a double lumen tube with one lung ventilation and independent lung ventilation was not an option. Conventional ventilation was tried initially but the patient did not respond. Measures to improve oxygenation such as increasing PEEP and inspiratory time were not feasible since they might have augmented the air leak and resulted in failure of ventilation. An extracorporeal ventilation facility was not available at that time.

HFOV has been used routinely in cases of refractory hypoxia of non-traumatic origin. However, in the light of recent trials its use has become quite controversial.⁷ These trials showed no benefit in outcomes. Conversely, the literature describing its use in trauma settings is relatively limited. There have been certain reports stating effective use of HFOV in ARDS and trauma. Briggs *et al*,⁸ in their retrospective analysis of 24 adult patients with injury induced ARDS, concluded HFOV was a safe and effective mode of ventilation for rescue therapy of refractory hypoxia. However, in this analysis survival was correlated to the extent of initial injury but not to the use of HFOV per se. Ha and Johnson⁹ used HFOV successfully in management of a post-thoracotomy high output bronchopleural fistula presenting with problems similar to our case and suggested its role in failure of conventional ventilation associated with a high output air fistula. Funk *et al*¹⁰ concluded early use of HFOV to be safe and efficacious in blunt trauma patients sustaining pulmonary contusions in their retrospective analysis. Galvin *et al*¹¹ also described a case of non-traumatic ARDS complicated by bilateral pneumothoraces and air leaks, managed effectively with use of HFOV. Nonetheless, to the best of our knowledge, successful use of HFOV to overcome a persistent air leak with underlying lung collapse, lung contusion associated with refractory hypoxaemia and eliminating the need for operative intervention has not been reported previously.

The major problems associated with a large persistent air leak in a ventilated patient are persistent lung collapse, ineffective delivery of tidal volume and inability to apply PEEP. The goal in a mechanically ventilated patient is to maintain permissible oxygenation and ventilation while reducing the flow from the fistula, permitting it to heal. This necessitates reduction of tidal volumes, inspiratory pressures, PEEP, inspiratory time, respiratory rate, and acceptance of permissive hypercapnia and lower normal range oxygen saturations. Most air leaks heal spontaneously within a few days. Often, the goal of desirable oxygenation and controlling of the air leak is not achieved despite the best possible conventional ventilator strategy, leading to refractory hypoxia and an operative intervention. Use of HFOV in such cases can obviate a need for operative intervention.

HFOV technique works on the principle of delivering small tidal volumes (1–4 mL/kg) at high frequencies (3–15 Hz) with an oscillatory pump. It generates high continuous distending pressure, which reduces from the ventilator to the distal trachea. It recruits the lungs more rapidly in comparison with conventional ventilation at similar distending pressures due to sustained increase of pressure over time and associated additive pressure distribution with oscillations.¹² These characteristics prevent a repeated opening–closing phenomenon of the alveoli and may recruit collapsing unstable alveolar units more efficiently than conventional ventilation. This mechanism might be speculated to have played in the successful management of our patient.

Learning points

- ▶ The potential benefit of high frequency oscillatory ventilation (HFOV) as part of management of a patient presenting with severe chest injuries associated with air leak syndrome.
- ▶ Early institution of this strategy could prevent a major surgical undertaking such as thoracotomy.
- ▶ Risks and benefits provided by instituting HFOV in cases of thoracic injuries associated with bilateral haemopneumothorax and refractory hypoxia need further research.

To conclude, HFOV represents a reasonable alternative in select cases presenting with high output air fistulas where there is a dual need to control the leak as well as to maintain acceptable oxygenation. Whether it should be used early in such cases or as a second-line option is debatable and warrants further research.

Competing interests None.

Patient consent Obtained.

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