HFOV in inhalational injury associated ARDS with broncho-pleural fistula – An old friend to the rescue: Case report

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Introduction: Patients with acute respiratory distress syndrome (ARDS) on mechanical ventilation often require high inspiratory pressure and positive end-expiratory pressure (PEEP). However, effective ventilation becomes difficult in cases where a large air leak develops in patients. The management of such a case requires improvisation and the adoption of special ventilation strategies.

Case and outcomes: We present a case study of a burn patient with airway involvement, developing ARDS and who developed a bronchopleural fistula (BPF) leading to failure of conventional ventilation. He was managed successfully with high-frequency oscillatory ventilation (HFOV) and finally discharged.

Conclusion: HFOV is a feasible option for ventilating patients with BPF when conventional ventilation fails. At a time when HFOV has largely been relegated to obsolescence, we hope to re-emphasize its relevance under particular circumstances.

Key Words: *acute respiratory distress syndrome; bronchial fistula; case report; high-frequency oscillatory ventilation*

INTRODUCTION

Patients with acute respiratory distress syndrome (ARDS) require high inspiratory pressure and PEEP for effective mechanical ventilation. However, effective ventilation becomes difficult in cases where a large air leak develops in patients. In these circumstances, conventional ventilation may be ineffective, mandating unique ventilation strategies, novel techniques and improvisation. Here we describe a case of ARDS with a large air leak due to a bronchopleural fistula (BPF), in which conventional ventilatory strategies failed. The patient was ultimately rescued using high-frequency oscillatory ventilation (HFOV) – a ventilatory mode rarely used in today's practice. Informed written consent was obtained from the patient before submission of the case report for publication.

CASE AND OUTCOMES

A 30-year-old man with no comorbidities was admitted to the burn care intensive care unit (ICU) at the All India Institute of Medical Sciences, New Delhi, with second- and third-degree thermal burns involving the head, face, chest and bilateral upper extremities (estimated 45% of total body surface area). On presentation, he was conscious, oriented and hemodynamically stable. Singeing of facial and nostril hair was noted, which, along with the mechanism and distribution of injury, suggested the possibility of airway involvement. A check flexible laryngoscopy and bronchoscopy were performed under topical anesthesia that showed mucosal hyperaemia and soot deposits at the laryngeal inlet and in the trachea-bronchial tree (Figure 1). Humidified oxygen, intermittent bronchodilator and mucolytic (N-acetyl cysteine) nebulization were administered.

Toward the end of the first week, the patient complained of gradually worsening shortness of breath, tachypnoea, tachycardia and progressively increasing oxygen requirement. The patient was switched from simple nasal prongs to high-flow nasal cannula. Chest x-ray showed gradual worsening of lung fields, with bilateral infiltrates and haziness of lower zones. Point-of-care ultrasound scanning showed bilateral B-profile, significant pleural effusion on both sides, and underlying collapse of the lung bases. Bilateral thoracocentesis was performed, draining approximately 800 ml of clear serous fluid from each side. Non-invasive ventilation was initiated. Despite these efforts, the patient's dyspnoea continued to worsen. Arterial blood gas (ABG) analysis showed a PaO_2 to FiO_2 (P/F) ratio of 90. Considering the worsening type-1 respiratory failure due to severe ARDS, the patient was intubated, paralyzed, and put on lung-protective mechanical ventilation on day 9 of the ICU stay. The team considered prone ventilation as it is recommended for improving oxygenation in patients with moderate-to-severe ARDS but decided against it due to extensive raw areas on the face, neck and chest. Ultrasound scanning on the second day of mechanical ventilation showed that significant bilateral pleural effusions had recurred. We opted to insert 20 F intercostal drainage tubes on either side instead of repeated thoracocentesis.

By the end of the second week, the patient started developing daily episodes of high-grade fever with an increase in purulence of tracheal secretion. Endotracheal aspirate (ETA) grew carbapenem-resistant *Acinetobacter baumannii* sensitive only to tigecycline and polymyxins, and antibiotic therapy was duly modified to treat ventilator-associated pneumonia (VAP). By this time, the patient had already developed severe muscle wasting and ICU-acquired weakness. Due to an already protracted course on a ventilator and in anticipation of prolonged weaning, a percutaneous tracheostomy was performed on day 10 of mechanical ventilation. Post tracheostomy, the patient was put on pressure-controlled

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FIGURE 1

Initial flexible bronchoscopy showing hyperaemic mucosa and soot deposits in the airway.

ventilation, and gradual weaning was started. However, lung compliance remained poor, requiring high driving pressure (ventilator settings: pressure control mode, FiO_2 50%, peak inspiratory pressure 24 cm – 28 cm H_2O, PEEP 8 cm H_2O).

On day 14 of mechanical ventilation, the patient developed a violent bout of coughing, followed by desaturation. Continuous bubbling was noted in the right-sided chest tube, coupled with hypotension and tachycardia. As the patient's saturation and vitals were worsening, a second large-bore chest tube was inserted on the right side. A massive air leak was observed from both the intercostal drainage tubes on the right side. Ventilation remained inadequate, and the patient continued to desaturate, with SpO_2 dropping to less than 50% on a FiO_2 of 100% over 10 min. As the large air leak from the right lung was making ventilation ineffective, we decided to selectively ventilate the intact left lung. The tracheostomy tube was removed, and a size 7 mm flexometallic endotracheal tube was inserted into the left main bronchus using a flexible bronchoscope. The cuff was then inflated, and selective left lung ventilation commenced. Partial success in ventilation was achieved, with SpO_2 rising to approximately 70% on a FiO_2 of 100%. However, further improvement in SpO_2 could not be achieved as the left lung itself was compromised due to the residual changes of ARDS. During the one-lung ventilation strategy, it was decided to attempt ventilation with a high-frequency oscillatory (HFO) ventilator. Once the HFO ventilator was ready, the flexometallic tube was withdrawn from the left bronchus into the trachea and connected to the HFO ventilator circuit via a straight connector. HFOV was initiated with the following settings: bias flow 40 L/min, amplitude (delta P) 80 cm H_2O, frequency 10 Hz, inspiratory ratio 33%, mean airway pressure (mPaw) 28 cm H_2O, and FiO_2 100%. Gas exchange improved within minutes of initiating HFOV, with SpO_2 rising to more than 90% and $PaCO_2$ gradually normalizing.

The HFOV strategy was tailored to minimize air leak while maintaining adequate gas exchange. Once the SpO_2 reached 90%, the FiO_2 was gradually reduced to 60%. Then, mPaw was incrementally reduced while ensuring SpO_2 remained above 90%. Once mPaw was below 20 cm H_2O, the FiO_2 was slowly reduced to 40%. The amplitude of oscillation was adjusted to ensure visual chest vibrations extending up to the mid-thighs. The patient was kept deeply sedated and paralyzed using propofol, fentanyl and cisatracurium infusions for the entire duration of HFOV. The air leak gradually reduced over the next 2 days, and the patient remained on HFOV for a total of 72 h. Once the patient was able to maintain SpO_2 above 90% on minimal HFOV parameters (ie, mPaw less than 12 cm H_2O and FiO_2 40%), he was switched to conventional ventilation with low tidal volume and PEEP of 5 cm H_2O. Once it was satisfied that the patient was maintaining adequate ventilation without re-opening the air leak, the paralytic was discontinued, the flexometallic endotracheal tube was changed to a cuffed tracheostomy tube, and the patient was placed on pressure support mode. Over the next 5 days, pressure support was slowly weaned, and the patient was given intermittent T-piece trials. The left-sided chest drain and the smaller right-sided chest drain were removed. Finally, on the 24th day following intubation, the patient's tracheostomy was decannulated, and the patient was switched to oxygen by nasal prongs. The remaining right-sided chest tube was removed on the 26th day.

Serial chest x-rays during the course of illness are depicted in Figure 2. After decannulation, a high-resolution CT scan of the thorax was performed to look for any residual changes. It showed pneumonic sequelae predominantly involving the right middle and lower lobes and a fistulous tract extending from the right middle lobe bronchus to the pleura. Both lungs were fully expanded, and there was no pneumothorax (Figure 3).

The remainder of the course in the ICU was uneventful. Deep breathing exercises, chest physiotherapy and incentive spirometry were gradually initiated. After 36 days of ICU stay, the patient was transferred to the hospital ward, underwent further burn wound care and skin grafting, and was finally discharged. The patient has been under regular follow-up and is able to perform activities of daily living independently.

DISCUSSION

This case report describes the successful use of HFOV in a case of ARDS with BPF, both as a rescue therapy and as a bridge to recovery. The exact cause of the BPF in our patient is difficult to determine. Potentially, the direct thermal injury to the bronchial passages may have caused a breakdown of the bronchial wall. Also, repeated suctioning of inflamed and friable airways may result in breach of the bronchial wall and air leak. Furthermore, our patient had developed VAP caused by *A. baumannii*, a known cause of necrotising pneumonia, and subsequent BPF [1]. High airway pressure required for ventilation during the ARDS stage may have aggravated any minor air leak. Finally, injury during chest tube insertion could have resulted in the BPF, although no complication was noted at the time of insertion.

The reported mortality of BPF is between 18% and 71%, depending on the underlying cause and the degree of air leak [2]. Management of BPF includes infection control, nutritional support and mechanical closure of the fistula either through endobronchial approach or surgical techniques [3]. BPF in patients under positive pressure poses a complex problem. Ventilation often becomes ineffective due to most of the

FIGURE 2

Serial x-rays of the patient. (A) before intubation, with bilateral infiltrates and lower zone opacities; (B) Post bilateral ICD insertion and intubation; (C) Post tracheostomy with bilateral ICDs in-situ; (D) 2 h post HFOV initiation, with right sided pneumothorax; (E) 48 h post HFOV initiation, pneumothorax nearly resolved; (F) Post switching from HFOV to conventional ventilation; (G) Post tracheostomy decannulation; (H) At hospital discharge.

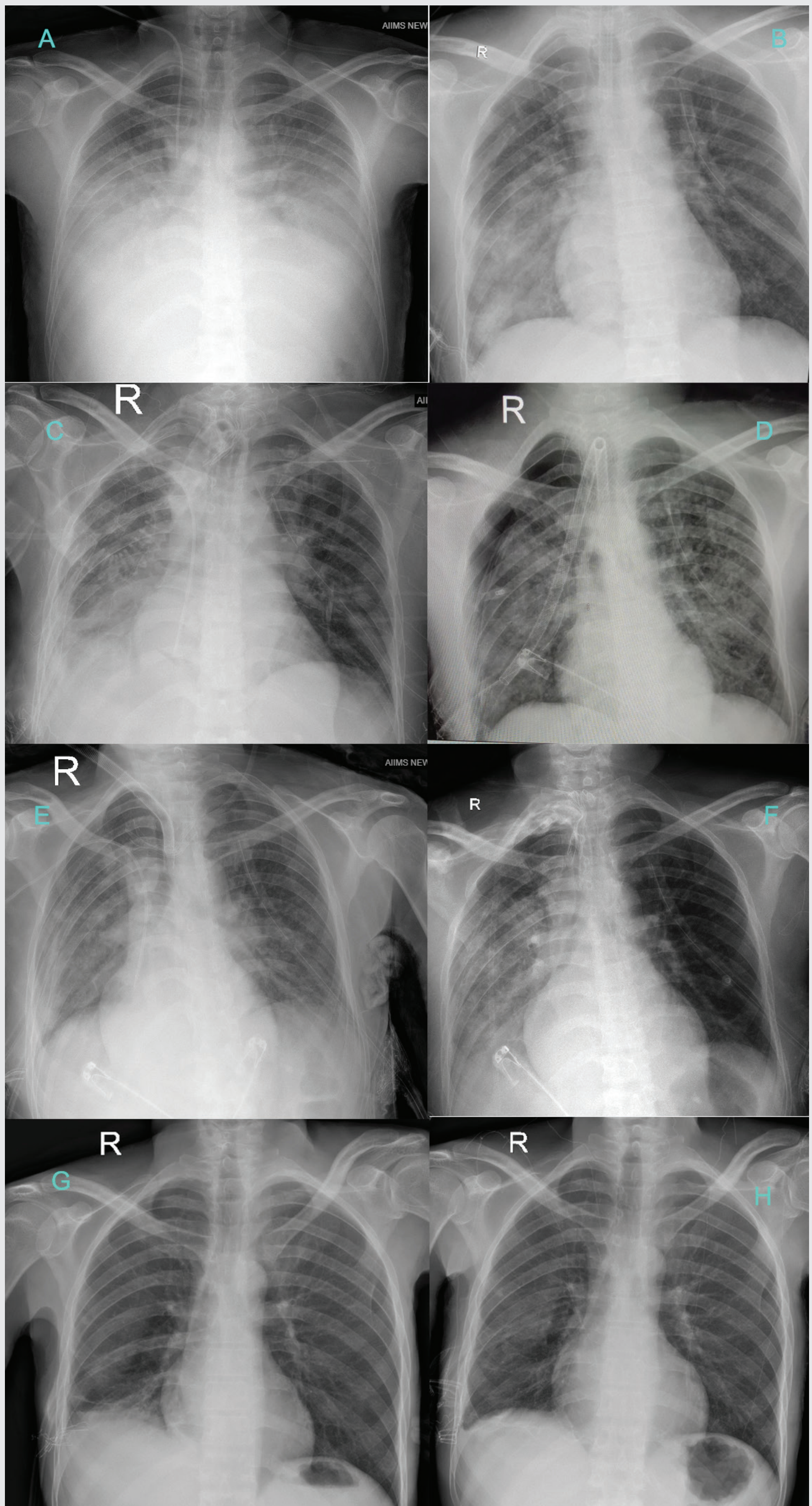
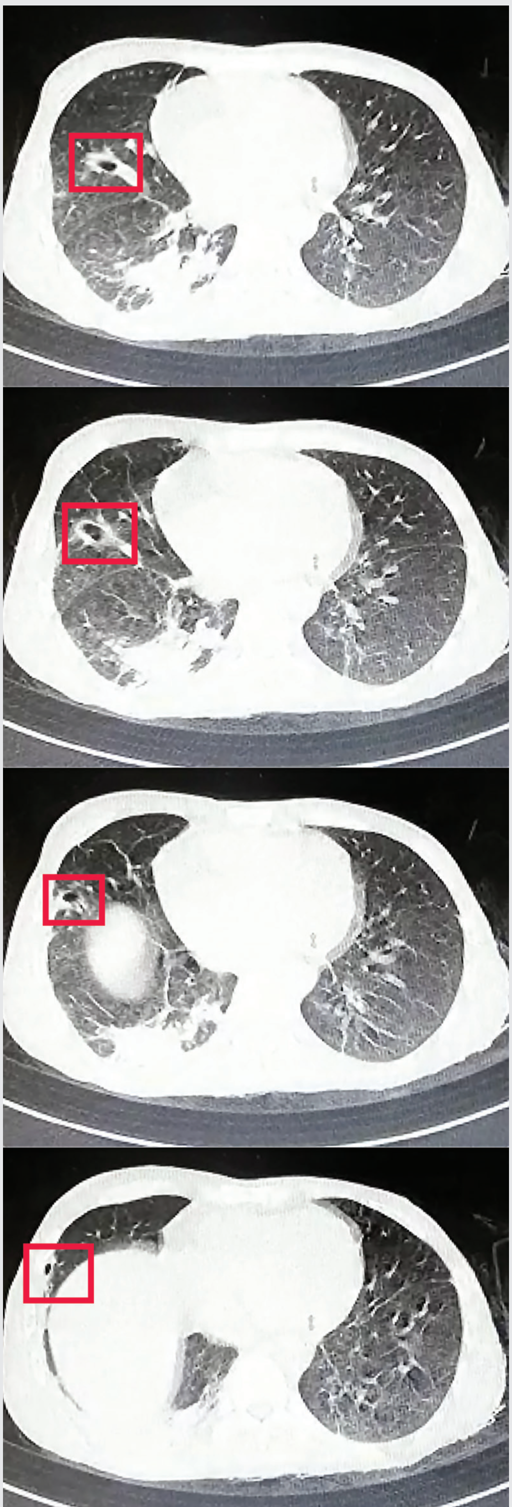


FIGURE 3

HRCT thorax showing the residual tract of the bronchopleural fistula from the right middle lobe bronchus to the pleural surface (top to bottom is cranio-caudal). Right middle and lower lobes show residual pneumonic changes.



delivered tidal volume leaking through the fistula. The goal of mechanical ventilation is to minimize air-leak and promote healing by keeping airway pressure below the critical opening pressure of the fistula and simultaneously achieve adequate inflation of the residual pulmonary segments. This can be achieved by minimizing PEEP, shortening inspiratory time, targeting low tidal volumes, using spontaneous modes whenever feasible, and permissive hypercapnia. Peak airway pressures over 30 cm H_2O should be avoided [3]. This conservative ventilation approach succeeds in many patients. However, some patients with large air-leaks, or those with poor compliance of the residual lung segments, may not be successfully ventilated at the above-described settings.

Theoretically, high-frequency ventilation (HFV) can achieve adequate gas exchange at lower peak pressures compared with conventional ventilation. Unlike conventional ventilation, HFV does not depend solely on bulk flow and does not require lung isolation. The two main modalities of HFV include high-frequency jet ventilation (HFJV) and HFOV. There are reports of successful use of HFJV in patients with BPF [4–6]. However, the largest case series failed to find any benefit of HFJV over conventional ventilation in patients with BPF in terms of a reduction in airway pressures or improvement in gas exchange [7]. In HFJV, lung inflation is achieved by a jet of air through a cannula inserted in the endotracheal tube and lung deflation is passive. Compared with HFOV, both lung inflation and deflation are active, accomplished by the oscillations of a membrane. This gives better control over small tidal volumes and avoids the risk of gas trapping and over-distension, as often seen with HFJV.

The successful use of HFOV in the management of BPF has been described in earlier reports, although none of them involved patients with underlying ARDS [8, 9]. For years, researchers have studied the use of HFOV in patients with ARDS. Though initial results were promising, two large-scale trials showed that HFOV does not have any advantage over conventional low-tidal volume ventilation, and may even increase mortality [10, 11]. As a result, the use of HFOV in adult ICUs has largely been abandoned. The presence of a major air leak along with ARDS, however, drastically changes the scenario. In such circumstances, when conventional ventilation fails, HFOV might be useful.

Veno-venous extra-corporeal membrane oxygenation (VV-ECMO) has emerged as a reliable management option for patients with BPF [12]. However, the cost, limited availability and logistical concerns often hinder its application. Although VV-ECMO was available at our centre, the presence of full-thickness burns involving the neck and upper part of the chest precluded its application as there was no suitable site available for insertion of the return cannula. We also opted not to use the femoro-femoral route for VV-ECMO as this would have required cannulation of both femoral veins, leaving us no option for a reliable central venous access. Other treatment options of BPF include endobronchial patching and valve placement in patients who can tolerate bronchoscopy and in whom the exact fistula site can be located. Flexible bronchoscopy was performed in our patient when his condition had stabilised and he had been switched to conventional ventilation. However, as the exact fistula site could not be visualized and the air leak had spontaneously resolved, no further intervention was undertaken.

CONCLUSION

HFOV is a useful ventilatory strategy that should be considered in the management of patients with large air leaks due to BPF. Unfortunately, HFOV ventilator management is a dying skill, and most HFOV machines have fallen into disrepair. If an HFOV machine is present in the ICU, it should be checked and maintained, repaired if necessary, and kept ready for rare situations such as the one described, where it may prove to be the difference between life and death.

DISCLOSURES

Contributors

Case management (RR, PKD, SR, AR, KDS), background research (RR, PKD), draft preparation (RR, PKD, SR, AR), draft review (PKD, KDS).

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Competing interests

All authors have completed the ICMJE uniform disclosure form and declare no conflict of interest.

Patient consent

Informed consent was obtained from the patient for publication of this report and clinical confidentiality has been maintained.

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