CASE SERIES

High-flow Tracheal Oxygenation: A New Tool for Difficult Weaning

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Abstract

High-flow tracheal oxygenation (HFTO), a modification of high-flow nasal cannula (HFNC), has been used in tracheostomized patients but only rarely for weaning. We present two cases on prolonged mechanical ventilation (PMV) where HFTO assisted weaning.

Keywords: High-flow tracheal oxygenation, Prolonged mechanical ventilation, Weaning.

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Introduction

Patients with severe lung diseases often end up in prolonged mechanical ventilation (PMV) with repeated weaning and extubation failures that are multifactorial in etiology for which various weaning modalities have been tried.[1] We present two cases, one with severe obstructive airway and another with restrictive lung disease who were weaned successfully by the application of high-flow tracheal oxygenation (HFTO) support.

Case Reports

Case 1

A 56-year-old female presented to the emergency room (ER) with respiratory distress and high-grade fever for the last two days. She had late-onset asthma with irreversible severe airflow obstruction [forced expiratory volume in 1s (FEV1): 0.69 L (42.6% of predicted) FEV1/forced vital capacity (FVC): 59.9%].

Initial physical examination revealed temperature 101 °F, respiratory rate 25/min, oxygen saturation 88% on room-air, and blood pressure 110/70 mm Hg. Use of accessory respiratory muscles was observed. There was an extensive bilateral expiratory wheeze. Rest of the systemic examination was normal. Laboratory studies were normal except for a total leukocyte count of 22.5 × 10^3/µL. Arterial blood gas analysis (ABG) showed pH 7.284, $PaCO_2$ 54.1 mm Hg, PaO_2 78.1 mm Hg, and HCO_3 26.7 mEq. Chest X-ray showed inhomogeneous opacities in the right lower zone with an air bronchogram sign.

She was started on bronchodilators, steroids and antibiotics, and a brief trial of non-invasive ventilation (NIV). Further worsening of respiratory distress led to elective mechanical ventilation.

Weaning

Her clinical condition improved over the next 5 days with a partial clearing of chest X-ray. She was weaned to pressure support ventilation (PSV), extubated, and put on NIV via facemask. But the patient rapidly became dyspneic with progressive hypoxemia and had to be re-intubated within two hours.

Due to repeated T-piece trial failures, percutaneous tracheostomy (PCT) was done on the eighth day of mechanical ventilation. Over the next four days, there were repeated failed trials of weaning with T-piece and with portable NIV via tracheostomy.

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After 12 days of conventional weaning attempt, HFTO (AIRVO 2, Fisher & Paykel Healthcare Ltd, Auckland, New Zealand) was introduced to facilitate weaning. The flow was initially set at 60 L/min and FiO_2 at 0.60. The patient was able to tolerate HFTO well for almost two hours without any signs of distress (Table 1). Encouraged by the favorable response, HFTO facilitated weaning protocol was drafted (Fig. 1A).

HFTO was connected twice daily in the morning and evening for two hours initially with PSV for the remaining part of the day. Gradually, the patient's oxygenation started showing signs of betterment with each session of HFTO and other respiratory parameters too crept towards normalcy (Fig. 1C). Sessions with HFTO were extended over the next 4–5 days. There was a progressively increasing PaO_2/FiO_2 ratio as the duration of HFTO increased to a full time on HFTO and a PaO_2/FiO_2 plateau was reached (Fig. 1C). Later the PaO_2/FiO_2 plateau was maintained even after decreasing this HFTO duration while weaning from HFTO.

Initially, the patient was rested in a control mode of ventilation during the night. The patient was gradually weaned off the ventilator for two weeks and decannulated on the 40th day after intubation and was subsequently discharged home. The patient is on follow-up for the last three years, maintaining well only on meter dose inhalers.

Case 2

A 24-year-old female was received in the ER from another hospital on a mechanical ventilator. Her vitals were HR = 136/min, BP = 100/60 mm Hg on noradrenaline infusion of 0.8 µg/kg/min,

Table 1: Various weaning modes attempted after tracheostomy in case 1

Settings	*T-piece trial*[1] 5 LPM of O_2	*NIV trial*[2] IPAP: 16, EPAP: 8 FiO_2: 40	*HFTO trial* Flow: 60 LPM FiO_2: 40
SpO_2 (%)			
15 min	95%	95%	97%
30 min	90% (TS)	93%	95%
60 min		88% (TS)	92%
120 min			95%
RR/min			
15 min	20	25	20
30 min	25 (TS)	30	18
60 min		42 (TS)	22
120 min			21
HR/min			
15 min	110	108	110
30 min	140 (TS)	125	105
60 min		142 (TS)	90
120 min			95
RDOS[3] (0–10)			
15 min	2	2	2
30 min	10 (TS)	2	1
60 min		10 (TS)	1
120 min			1

[1]Last T-piece trial before HFTO trial attempted; [2]Last NIV trial before HFTO trial attempted; [3]The respiratory distress observation scale (RDOS) is an observational tool developed as a scale to assess respiratory distress in mechanically ventilated patients undergoing a weaning trial as they are unable to report dyspnea; IPAP, inspiratory positive airway pressure; EPAP, expiratory positive airway pressure; TS, trial stopped; LPM, liters per minute; HR, heart rate; BP, blood pressure; RR, respiratory rate

RR = 20/min, SpO_2 = 90% on FiO_2 of 100%, the control mode of ventilation. ABG showed pH 7.257, PCO_2 94.7 mm Hg, PO_2 63.0 mm Hg, HCO_3 41.3 mEq.

In the previous hospital, she was managed as a case of bilateral pneumonia for the last ten days and was put on a mechanical ventilator five days back because of type-2 respiratory failure.

We initiated lung-protective ventilation as per acute respiratory distress syndrome (ARDS) protocol. A computed tomography (CT) thorax revealed bilateral diffuse reticulonodular shadows with extensive fibrosis and traction bronchiectasis in bilateral upper lobes. Transbronchial biopsy revealed histological features of organizing pneumonia. Methylprednisolone 40 mg once daily was started and after one week, the dose was tapered to a daily dose of 20 mg for two weeks, 12 mg for 2 weeks, and 8 mg for 4 weeks.

Weaning

Gradually, the patient improved on the above treatment and was weaned to pressure support (PS) ventilation. But, on PS mode, she was tachypneic and generated tidal volumes of a mere 200–250 mL with the inspiratory support of 20 mm Hg.

After a week of ventilation in our unit, she underwent PCT but weaning attempts with PSV or T-piece trials failed repeatedly.

Thereafter, HFTO was introduced with a weaning protocol (Fig. 1B). The sessions of HFTO were extended on daily basis depending on her previous day's response. She tolerated HFTO trials well and her compliance with HFTO improved over days (Fig. 1D). HFTO was continued for over 15 days. She was encouraged to sit at the bedside, drink, eat, and even walk while supported by HFTO. She also performed muscle strengthening limb exercises that assisted HFTO including cycling on a frame attached to the patient's bed (Fig. 2D and E). Slowly and steadily she was completely shifted to high flow oxygenation from a mechanical ventilator. As shown in Figure 1D, progressively increasing PaO_2/FiO_2 ratio noted as the duration of HFTO increased until full time on HFTO but here a plateau is reached with a suboptimal PaO_2/FiO_2 ratio.

However, every attempt to switch her to T-piece from HFTO failed. Hence, she was decannulated (bypassing T-piece trials) and put on HFNC (Fig. 1F). She was managed on HFNC for the next four days and even shifted to the ward. After four days HFNC was replaced with oxygen via nasal prongs and the patient was discharged after another day on home oxygen. She is still on follow-up for 18 months and can carry out all her daily activities of life on room air.

Discussions

High-flow nasal cannula (HFNC) is a high-flow delivery system.[2] Heated and humidified oxygen is delivered at fixed FiO_2 and has many beneficial physiological effects, such as better clearing of the airway secretions,[3] positive end-expiratory pressure (PEEP) effect,[4] and flushing out carbon dioxide effectively.[5] In critically ill patients HFNC is being put to innovative usage in patients with respiratory failures.[2,6]

A prospective pilot monocentric study in acute respiratory failures (majority hypercapnic respiratory failures)[7] revealed HFNC used was associated with significant and brisk improvement in respiratory rate, thoracic abdominal asynchrony, and oxygenation. Here, patients with HFTO in two cases showed progressive improvement in PF ratio till plateau was reached. The two patients reached different levels of the plateau. A subnormal level of the plateau, as in case 2 was an indicator that the patient was not ready to be weaned directly from HFTO.

In a study incidence of post-extubation, respiratory failure after 72 hours was significantly less in the HFNC group (n = 264) as compared to the conventional oxygen therapy (COT) group (n = 263) (4.9 vs 12.2%; p value = 0.004) but overall ICU stay and mortality were similar in both the groups.[8] In this study, a crossover was not allowed and the patients who were at low risk of extubation failure were included. In another study compared HFNC (n = 290) with noninvasive ventilation (NIV) (n = 304) in patients with a high risk of extubation failure[9] concluded that HFNC is non-inferior to NIV when used as prophylactic respiratory support in planned extubated patients with regard to the incidence of reintubation, ICU stays and mortality in both the groups. However, HFNC offered greater comfort to the patients. Similar favorable results with HFNC have been reported in the pediatric age group too.[10]

There are limited data on the use of HFNC facilitated weaning of tracheostomized patients.[11] In tracheostomized patients, HFTO may have different physiological effects from HFNC because of the different interface. No improvement in the neuro-ventilatory drive, work of breathing, respiratory rate, and the gas exchange was observed with HFTO compared with COT after disconnection from

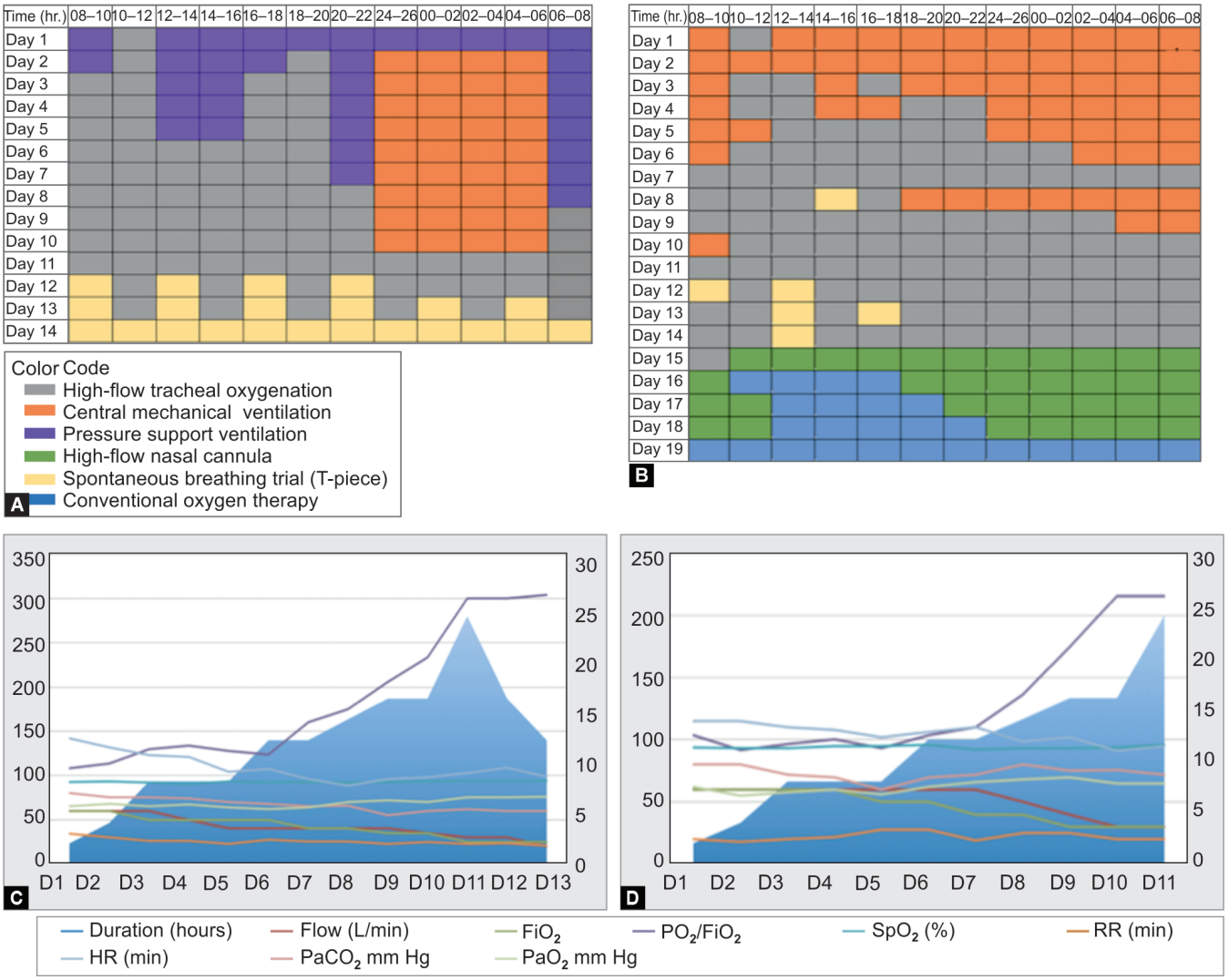

Fig. 1: Weaning protocol used for case 1 (A) and case 2 (B). Note: On Day 15, case 2 was directly put on HFNC without any T-piece trial. Lower panel illustrates the changes in the respiratory parameters (on left axis) of case 1 (C) and case 2 (D) while on HFTO. Note the significant improvement in P/F ratios (purple lines on left axis) in both cases as the durations of HFTO (Blue plots on right axis) increases till full-time HFTO ventilation is reached

the ventilator in tracheostomized patients at high risk of weaning failure from mechanical ventilation.[12]

Natalini et al. enrolled 17 tracheostomized patients for HFTO at different gas flows of 10, 30, and 50 L/min, and their effects on oxygenation, respiratory rate, and tracheal pressures were observed.[13] They inferred that as the gas flows were increased, there was a significant improvement in oxygenation (p value < 0.001) and also a modest increase in tracheal pressure (p value = 0.01). There was no change in respiratory rate and $PaCO_2$.

The main concern in the tracheostomized patient is the inadequate humidification of inhaled gasses as the tracheostomy track bypasses the natural humidification process. This causes drying of the secretions and atelectasis resulting in weaning failure of the PMV patients. This detrimental effect is negated by the use of HFTO by providing heated oxygen at more than 30 mg/L of absolute humidity (AH), i.e., 100% of relative humidity (RH).[14] Hence, the heated and humidified delivery of oxygen to the tracheostomized patient via HFTO closely matches the physiological humidification in contrast to suboptimal humidification by NIV.

HFTO is considered to be an open circuit, but the high inspiratory flow gives a "PEEP effect" throughout the respiratory cycle. At inspiratory flows of 40–60 L/min, a PEEP of almost 4–6 mm Hg is created.[1,11] This perhaps counteracts "the dynamic hyperinflation" of the lungs in very severe obstructive airway disease when they are put on spontaneous breathing trial (SBT). It also negates the backward failure, commonly seen in these patients with associated right heart failure.

Corley et al. in their randomized crossover study on 20 tracheostomized patients compared physiological benefits of HFTO ventilation as compared to low-flow T-piece ventilation.[15] They found significantly better oxygenation of HFTO group at 5 minutes (p value = 0.002) and 15 minutes (p value = 0.001) and a significant elevation in their positive airway pressures as compared to T-piece (mean difference of +0.7 cm H_2O, p value = 0.001) but no effect on end-expiratory lung volume (EELV).

Recently, Mitaka et al. reported successful weaning of two PMV patients with restrictive pulmonary function.[16] He observed that high inspiratory oxygen flow facilitates weaning by enhancing tidal

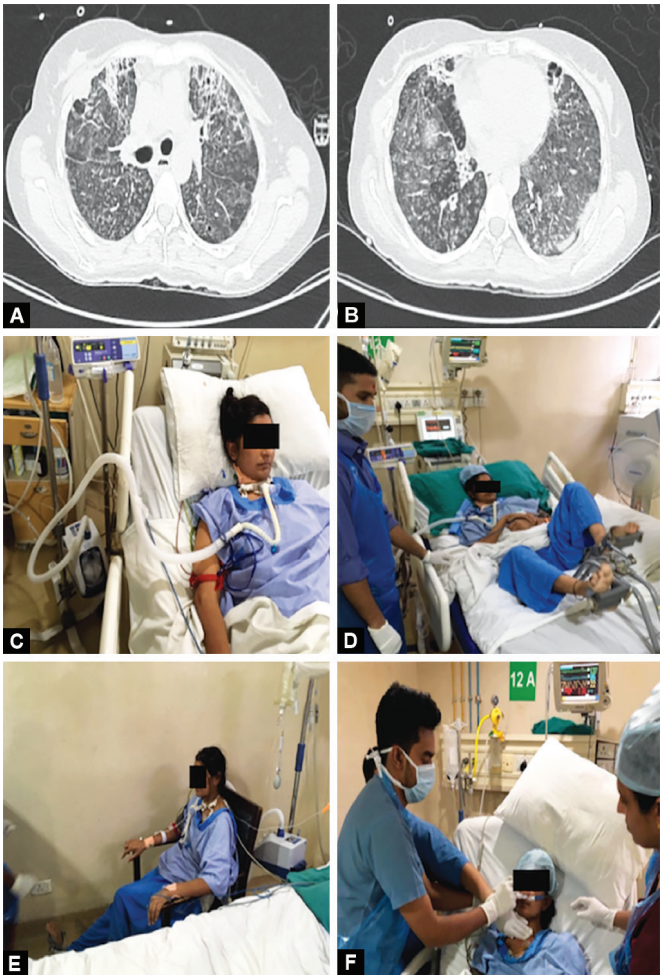

Fig. 2: (A and B) CT chest images of case 2. Patient on HFTO (C). Physiotherapy and cycling while patient is on HFTO (D–E), patient on HFNC (F)

volume and reducing their inspiratory efforts and work of breathing. He further suggested that in contrast to their study, Corley et al., failed to exhibit an increase in EELV as their patients were more generalized and lacked any restrictive pulmonary dysfunction.

To the best of our knowledge, successful weaning by HFTO in prolonged ventilated patients with obstructive lung disease has never been carried out. Our first patient failed several weaning attempts on NIV and spontaneous breathing trials (T-piece) via tracheostomy. Successful weaning with the use of HFTO along with a well-structured weaning protocol, as demonstrated by us, was the first of its kind. In the second case, we used HFTO followed by HFNC to wean off a restrictive lung disease patient and even supported rehabilitation measures. This too has rarely been reported earlier. Future randomized controlled trials are needed to establish the role of HFTO in weaning tracheostomized patients with either obstructive airway disease or restrictive disorder on PMV with difficult weaning.

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