◉ Case Report ◉

Severe Obstructive Respiratory Failure Successfully Treated with High-Frequency Oscillatory Ventilation

Kohei OTA, Shinichiro OHSHIMO, Yoshiko KIDA, Tomoko TAMURA
Kazunobu UNE, Tadatsugu OTANI, Satoshi YAMAGA, Yasumasa IWASAKI
Nobuyuki HIROHASHI, Koichi TANIGAWA

Key words：active expiration, air-trapping, auto-PEEP, barotrauma, lung-protective ventilation

Abstract

High-frequency oscillatory ventilation（HFOV）is a lung-protective ventilatory method that prevents airway collapse and overdistention of the lung. For severe obstructive pulmonary diseases, however, the indication of HFOV is limited because of the risk of barotrauma and air-trapping. A very limited number of adult cases with obstructive respiratory failure successfully treated with HFOV have been reported. We present an adult case of obstructive respiratory failure due to bronchiolitis obliterans in which HFOV was effective as ventilatory management.

A 78-year-old male with bronchiolitis obliterans complicated by paraneoplastic pemphigus developed respiratory failure with severe hypercapnia, and eventually required mechanical ventilation. Conventional mechanical ventilation yielded a limited improvement in hypercapnia and acidemia because of severe airway obstruction. After initiating HFOV, however, hypercapnia, acidemia and impaired consciousness markedly improved. With the administration of methylprednisolone（1,000mg/body）, the patient was weaned from HFOV and discharged without ventilatory support. In conclusion, HFOV appears useful for selected adult patients with obstructive pulmonary disease.

Introduction

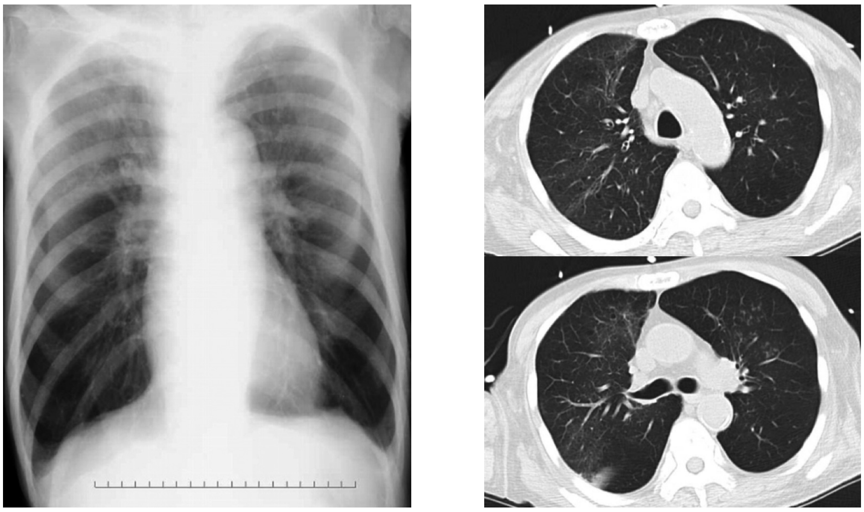
High-frequency oscillatory ventilation (HFOV) is one of the lung-protective ventilatory modes that rapidly delivers small tidal volumes with high mean airway pressures (MAP), decreasing the shear stress on alveoli[1]. The beneficial effects of HFOV in adult and pediatric cases with severe respiratory failure have been demonstrated[1, 2]. However, because of the risk of barotrauma or air-trapping, the indication of HFOV is limited in patients with severe obstructive pulmonary diseases such as emphysema or asthma[3]. Although there were reports of pediatric obstructive respiratory failure successfully treated with HFOV[4], few reports on adult cases have been found in the literature.

Bronchiolitis obliterans with paraneoplastic pemphigus is a life-threatening disease, frequently complicated by non-Hodgkin lymphoma, chronic lymphocytic leukemia and Castleman disease[5]. Respiratory impairment is the leading cause of death, and the mortality rate is estimated at approximately 90%[6]. We present an adult patient with severe obstructive respiratory failure due to bronchiolitis obliterans with paraneoplastic pemphigus who was successfully treated with HFOV.

Case Report

A 78-yr-old male visited the outpatient clinic of the

Department of Emergency and Critical Care Medicine,
Graduate School of Biomedical Sciences, Hiroshima University
［Received September 15, 2011：Accepted May 29, 2012］



（A）　　　　（B）

Fig. 1　（A）Chest radiograph showing bilateral hyperinflation.（B）Chest computed tomography showing a newly emerged ground-glass attenuation corresponding to air-trapping in bilateral lung fields.

department of dermatology of Hiroshima University Hospital in October 2008 complaining of systemic blistering. He was diagnosed as having plasmacytoma complicated by paraneoplastic pemphigus, and started on oral corticosteroids.

In April 2009, he presented with dyspnea characterized by a mild prolongation of expiration. Radiological findings of the chest showed bilateral pulmonary overdistention. He was diagnosed as having bronchiolitis obliterans, and treated with a higher dose of oral corticosteroids and bronchodilators and transient improvement of the symptoms were observed.

In January 2010, his respiratory symptoms gradually worsened, resulting in hypercapnia and impaired consciousness. He was admitted to the intensive care unit for ventilatory support.

The patient's height and weight were 163cm and 38kg. No obvious abnormality of the upper airway was found. However, he was tachypneic, and prolonged expiration and auscultatory attenuation of respiratory sound were observed on ICU admission. Arterial blood gas (ABG) analysis under 5 L/min oxygen with a face mask demonstrated uncompensated respiratory acidosis (pH 7.157, Pa_{CO_2} 114mmHg, Pa_{O_2} 124mmHg, base excess (B.E.) 10.3mEq/L). A chest radiograph showed hyperinflation in the bilateral lung field, and chest computed tomography (CT) demonstrated newly emerged diffuse air-trapping (**Fig. 1**). The patient was hypotensive with systemic blood pressure of 90mmHg. Laboratory findings showed leukocytosis (WBC : 12,270/μL, neutrophil : 84%), anemia (hemoglobin : 7.8g/dL), and an increase in C-reactive protein (1.11mg/dL). However, there were no elevation of procalcitonin and β-D-glucan levels, and no symptoms of cardiac failure.

Based on these findings, this patient was diagnosed as having acute exacerbation of bronchiolitis obliterans. Because of his impaired level of consciousness, he was intubated and initially ventilated with conventional mechanical ventilation (CMV). Although we used a volume-controlled ventilation with a small tidal volume of 350mL (6 mL/kg) to avoid alveolar hyperinflation, MAP was estimated above 25cmH_2O and the inspiratory peak, plateau and end-inspiratory airway pressure remained extremely high (>50cmH_2O) (F_{IO_2} 0.4, respiratory rate 18/min, positive end expiratory pressure (PEEP) 5 cmH_2O, inspiration-to-expiration ratio was ranged from 1 : 2 to 1 : 4). The constant plateau pressure levels despite the increment of PEEP and the presence of end-expiratory airway flow suggested the presence of auto-PEEP, which was estimated to be above 10cmH_2O according to the procedure described by Marini et al.[7] ABG analysis obtained after the

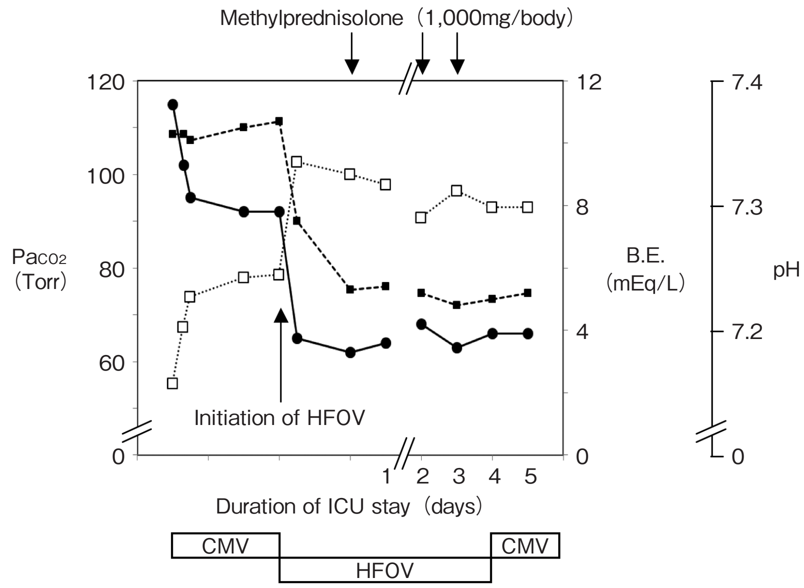


Fig. 2　Clinical course of the patient showing rapid improvement in hypercapnia after the initiation of HFOV. Closed circles indicate Pa_{CO_2}, closed squares indicate B.E., and open squares indicate pH. Pa_{CO_2}, partial pressure of arterial carbon dioxide；B.E., base excess；HFOV, high-frequency oscillatory ventilation；CMV, conventional mechanical ventilation.

initiation of CMV showed limited improvement in hypercapnia and acidemia (pH 7.24, Pa_{CO_2} 92mmHg and B.E. 11mEq/L). Although we tried pressure-controlled ventilation with various PEEP settings and airway pressure release ventilation, the effective ventilatory management was quite difficult because of the insufficient airway stenting or the extremely high airway pressure. The improvements in hypercapnia and acidemia were limited, and the patient has become more restless. Eventually, we switched to HFOV (R100, Metran Co.,Ltd., Saitama, Japan) (F_{IO_2} 0.4, MAP 30cmH_2O, frequency 10Hz, stroke volume 150mL, base flow 20L/min). We did not use muscle relaxants because the patient was very lethargic. The patient was sedated appropriately with 1 mg/hour of midazolam. Following the initiation of HFOV, MAP became stable and no pulmonary injuries such as pneumothorax were observed. The amplitude was decreased from 120cmH_2O to 80cmH_2O. ABG showed a marked improvement (pH 7.33, Pa_{CO_2} 65mmHg and B.E. 7.5mEq/L) (**Fig. 2**). We gradually tapered the settings of HFOV based on the ABG data and/or the amplitude monitoring to minimize the risk of barotrauma and to avoid acidemia (F_{IO_2} 0.3, MAP 18cmH_2O, frequency 6 Hz, stroke volume up to 285mL). Thereafter, we maintained the same settings for the following 4 days in combination with methylprednisolone (1,000mg/body) and antibiotics. The findings in ABG analyses, chest radiographs, and vital signs including blood pressure and heart rate continued to improve. On day 5, the ventilator mode was switched back to CMV (pressure controlled- synchronized intermittent mandatory ventilation (SIMV), F_{IO_2} 0.35, peak pressure 25cmH_2O, PEEP 5 cmH_2O, respiratory rate 20/min, inspiration-to-expiration ratio 1 : 2) and the patient was smoothly weaned from the ventilator. He was successfully extubated on day 23 and discharged to the rehabilitation center 4 months later. No barotrauma was observed in this patient.

Discussion

Bronchiolitis obliterans complicated by paraneoplastic pemphigus is a rare but potentially life-threatening disease due to severe obstructive respiratory failure [5]. Dynamic air-trapping and a resultant barotrauma are the severe complications during ventilation that should be avoided. Therefore, the monitorings of flow-volume curve and chest radiograph are important.

A number of different mechanisms of gas transport have been identified in HFOV[8]. Sufficient high PEEP in HFOV is advantageous for opening collapsed airways and keeping them open throughout the entire respiratory cycle without injurious peak airway pressures[9]. Because the peak and plateau airway pressures during CMV were extremely high in our patient even when considering the effect of panting, we did not try higher PEEP for fear of barotrauma. The mechanisms of molecular diffusion and/or pendelluft in HFOV may have complementary assisted in our patient with restlessness and irregular respiration.

The occult regional hyperinflation and air-trapping are the important issues that should be argued. These issues are important especially in adults because of the high prevalence of underlying obstructive pulmonary diseases[10]. Courtney et al. have demonstrated the utility of chest radiograph to evaluate the lung volume during HFOV, and found that ideal lung volume could be defined as expansion to 8 to 9.5 ribs[11]. Pellicano et al. have shown that the utility of chest CT to evaluate the lung volume and atelectasis[12]. In our patient, however, no significant change was observed in the radiological findings during HFOV. Pillow et al. have investigated the effect of the inspiration-to-expiration ratio on the magnitude of air-trapping[13]. Mean alveolar pressure fell below mean pressure at the airway opening during HFOV at the inspiration-to-expiration ratio of 1 : 2, whereas the difference between these pressures was minimal at the inspiration-to-expiration ratio of 1 : 1. These observations may assist in the determination of optimal settings of HFOV.

Of the various forms of high-frequency ventilation including high-frequency jet ventilation, HFOV is the only mode that enables active expiration. The benefit of active expiration is the active removal of CO_2[14]. However, clinicians should be aware that excessive active expiration may cause airway collapse and further air-trapping.

In summary, we presented an adult case of severe obstructive respiratory failure due to bronchiolitis obliterans successfully treated with HFOV. Further studies are needed to clarify the pathophysiology underlying the successful use of HFOV in patients with obstructive pulmonary disease.

References

1) Chan KP, Stewart TE, Mehta S：High-frequency oscillatory ventilation for adult patients with ARDS. Chest. 2007；131：1907-1916.
2) Arnold JH, Anas NG, Luckett P, et al：High-frequency oscillatory ventilation in pediatric respiratory failure：a multicenter experience. Crit Care Med. 2000；28：3913-3919.
3) Wratney AT, Gentile MA, Hamel DS, et al：Successful treatment of acute chest syndrome with high-frequency oscillatory ventilation in pediatric patients. Respir Care. 2004；49：263-269.
4) Berner ME, Hanquinet S, Rimensberger PC:High frequency oscillatory ventilation for respiratory failure due to RSV bronchiolitis. Intensive Care Med. 2008；34：1698-1702.
5) Anhalt GJ, Kim SC, Stanley JR, et al:Paraneoplastic pemphigus. An autoimmune mucocutaneous disease associated with neoplasia. N Engl J Med. 1990；323：1729-1735.
6) Mimouni D, Anhalt GJ, Lazarova Z, et al：Paraneoplastic pemphigus in children and adolescents. Br J Dermatol. 2002；147：725-732.
7) Marini JJ：Dynamic hyperinflation and auto-positive end-expiratory pressure：lessons learned over 30 years. Am J Respir Crit Care Med. 2011；184：756-762.
8) Pillow JJ：High-frequency oscillatory ventilation：mechanisms of gas exchange and lung mechanics. Crit Care Med. 2005；33：S135-S141.
9) Luecke T, Herrmann P, Kraincuk P, et al：Computed tomography scan assessment of lung volume and recruitment during high-frequency oscillatory ventilation. Crit Care Med. 2005；33：S155-S162.
10) Easley RB, Lancaster CT, Fuld MK, et al：Total and regional lung volume changes during high-frequency oscillatory ventilation（HFOV）of the normal lung. Respir Physiol Neurobiol. 2009；165：54-60.
11) Courtney SE, Durand DJ, Asselin JM, et al：High-frequency oscillatory ventilation versus conventional mechanical ventilation for very-low-birth-weight infants. N Engl J Med. 2002；347：643-652.
12) Pellicano A, Tingay DG, Mills JF, et al：Comparison of four methods of lung volume recruitment during high frequency oscillatory ventilation. Intensive Care Med. 2009；35：1990-1998.
13) Pillow JJ, Neil H, Wilkinson MH, et al：Effect of I/E ratio on mean alveolar pressure during high-frequency oscillatory ventilation. J Appl Physiol. 1999；87：407-414.
14) Bancalari A, Gerhardt T, Bancalari E, et al：Gas trapping with high-frequency ventilation：jet versus oscillatory ventilation. J Pediatr. 1987；110：617-622.