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Case report

A case of severe acute exacerbation of Yokkaichi asthma treated with a vibrating mesh nebulizer

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ABSTRACT

Yokkaichi asthma was one of the most common environmental pollution diseases in Japan in the 1960s and 1970s. The problem of air pollution in Yokkaichi was solved in the 1970s. However, mortality and life expectancy were still affected by the late effects of air pollution in patients with Yokkaichi asthma even in the 2000s. In this case report, we described the experience of successful treatment of a patient with severe asthmatic status due to Yokkaichi asthma. A 40s-year-old man, who was officially certified as a patient with Yokkaichi asthma from his infancy, was admitted to hospital due to acute exacerbation of asthma. Mechanical ventilation, intravenous administration of aminophylline and dexamethasone, enteral administration of montelukast, and a transdermal patch of tulobuterol were started. However, because of the lack of improvement in clinical status, inhalation of procaterol using vibrating mesh nebulizer systems was started. Inhalation of procaterol was used three times a day. After using the vibrating mesh nebulizer, respiratory system compliance and hypercapnia rapidly improved. Bilateral expiratory wheezing was diminished. Weaning from mechanical ventilation was initiated, and on the eighth day of mechanical ventilation, the patient was extubated. Although intractable respiratory failure with decreased respiratory system compliance resulting from the late effects of air pollution and a long-time asthmatic inflammatory condition was observed, the use of a vibrating mesh nebulizer for the inhaled administration of procaterol was useful to relieve severe bronchospasm due to Yokkaichi asthma.

1. Introduction

Yokkaichi asthma, caused by Yokkaichi air pollution, was one of the most common environmental pollution diseases in Japan in the 1960s and 1970s [1–3]. The air pollution problem in Yokkaichi was solved in the 1970s. There have been no new patients with Yokkaichi asthma since 1988 [1]. Since air pollution is emerging as a significant environmental issue in developing countries as they become industrialized, Japan's experience with environmental pollution and healthcare management has been attracting attention recently [3]. Meanwhile, it was reported that mortality and life expectancy were still affected by the late effects of air pollution in patients with Yokkaichi asthma, even in the 2000s [1]. However, there was no report regarding the recent medical status of individuals, especially in severe cases. In this case report, we described the experience of successful treatment of a patient with severe asthmatic status due to Yokkaichi asthma.

2. Case

A 40s-year-old man, 170 cm, 86 kg, was admitted to a hospital due to acute exacerbation of asthma. He was officially certified as a patient with Yokkaichi asthma from his infancy. He had a history of multiple hospitalizations and medical treatment for more than 40 years for Yokkaichi asthma. Until recent times, outpatient treatment had been continued by using fluticasone and salmeterol oral inhalation powder. He had no smoking history.

Although the arterial blood gas (ABG) result at the time of administration showed no significant deterioration in pH 7.42, $PaCO_2$ 39 mmHg, and PaO_2 74 mmHg, a disturbance of consciousness accompanied by breathing difficulty developed after the

Abbreviations: ABG, arterial blood gas; FiO_2, fraction of inspired oxygen; ICU, intensive care unit; $PaCO_2$, partial arterial carbon dioxide pressure; PaO_2, partial pressure of arterial oxygen; PEEP, positive end-expiratory pressure; P/F ratio, PaO_2 /FiO_2 ratio.

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arterial insertion for blood sampling. However, mechanical ventilation via endotracheal tube was started, and the worsening respiratory status with low exhaled tidal volume (200–300 ml) was observed. Because of the lack of improvement in clinical status, the patient was transported to our intensive care unit (ICU).

As for the initial mode of mechanical ventilation in ICU, assist-controlled pressure ventilation was chosen with a plateau pressure of 20 cmH_2O, a fraction of inspired oxygen (FiO_2) of 1.0, and a positive end-expiratory pressure (PEEP) level of 5 cmH_2O using a Puritan Bennett 840 ventilator (Covidien, Boulder, CO, USA). Sedation for mechanical ventilation was maintained with midazolam, dexmedetomidine, and fentanyl. Decreased respiratory system compliance on the first day of ICU was observed (median 12.2, range 10.7–26.7 ml/cmH_2O). The patient's respiratory system compliance was evaluated as a dynamic compliance, calculated using the following equation: Tidal volume/(Peak airway pressure-PEEP). Bilateral expiratory wheezing was heard on chest auscultation. Subsequent ABG demonstrated worsening of acute respiratory acidosis (pH 7.30, $PaCO_2$ 88 mmHg, and PaO_2 345 mmHg). With a diagnosis of severe asthmatic status due to Yokkaichi asthma, intravenous administration of aminophylline 500 mg/day and dexamethasone 16 mg/day was started. Enteral administration of montelukast 10 mg/day and a transdermal patch of tulobuterol 30 μg were started. Because of the serologic evidence of mycoplasma antibody titers, we concerned Mycoplasma pneumoniae infection as a possible cause of acute exacerbation of asthma. Intravenous administration of azithromycin 500 mg/day was also started. In spite of these intensive care measures, the patient's respiratory condition did not improve. Decreased respiratory system compliance and hypercapnia were still observed on the third day in ICU (Fig. 1).

On the fourth day in ICU, inhalation of procaterol 30 μg (0.3 ml of 0.01% solution) using vibrating mesh nebulizer systems (Aeroneb Solo, Aerogen Ltd., Galway, Ireland), which were placed in the inspiratory limb of a ventilator circuit, was started. Contrary to our plan for prompt administration of inhaled procaterol, it took three days to arrange the nebulizer, which was available in a ventilator circuit without the interference of mechanical ventilation. Respiratory system compliance rapidly improved during and after use of the vibrating mesh nebulizer (before: 22 ml/cmH_2O; after: 36 ml/cmH_2O). Inhalation of procaterol was used three times a day. Hypercapnia was also improved on the fourth to the fifth day in ICU. Bilateral expiratory wheezing was diminished. Weaning from mechanical ventilation was initiated, and on the eighth day in ICU, the patient was extubated. Thoracic computed tomography, which was taken after the patient's discharge from ICU, demonstrated the presence of marked bronchial wall thickening with minimal traction bronchiectasis and small emphysema. In addition, persisting obstructive and restrictive lung disease patterns were observed in the spirometry measurement conducted ten days after discharging the patient from ICU.

3. Discussion

Sulfur dioxide, the main component of air pollution in Yokkaichi, was related to Yokkaichi asthma [2]. Sulfur dioxide acts to contract the bronchial smooth muscle based on airway irritation, which causes bronchial wall thickening and fibrosis [4]. The effect of sulfur dioxide on the respiratory system could cause long-term complications. The early life exposure to the air pollutants in utero and during the first year can cause chronic inflammatory disorder of the airways that caused childhood asthma [5]. According to the findings in autopsy cases, the lungs showed predominantly a progression of interstitial pneumonia in four patients with Yokkaichi asthma [6]. Findings in the thoracic computed tomography of this case were consistent with asthmatic patients with interstitial lung damage. Although the exposure to sulfur dioxide in this case was only in infancy, the patient's severe asthmatic status based on obstructive and restrictive lung dysfunction might be caused by the late effects of sulfur dioxide poisoning and the long-time asthmatic inflammatory condition.

In this case, the patient had already been medicated using fluticasone and salmeterol oral inhalation powder. These medications were unable to prevent asthmatic symptoms due to Yokkaichi asthma. Contrary to this medical history, inhalation of procaterol 30 μg using vibrating mesh nebulizer systems was effective for the treatment of asthmatic symptoms and the recovery from decreased respiratory system compliance. Inhaled short-acting beta 2-

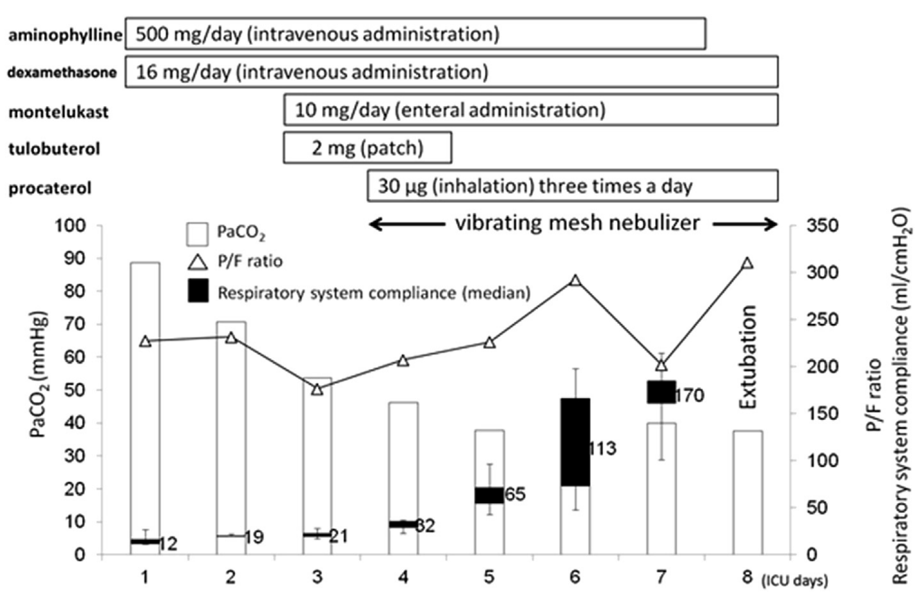

Fig. 1. Medications and time-course changes of respiratory status after ICU admission. Respiratory system compliance and hypercapnia improved after procaterol inhalation using a vibrating mesh nebulizer. Pulmonary oxygenation expressed by PaO_2/FiO_2 ratio (P/F ratio) was maintained around 200 to 300 during ICU stay.

adrenergic agonists, such as procaterol, are the foundation of treatment for acute asthma exacerbation because of their immediate onset of action and potent bronchodilator properties [7]. The effect of inhaled treatment depends on the size of the aerosol particles. Smaller aerosol particles can produce greater drug delivery when using nebulizer systems during mechanical ventilation [8]. The optimal particle size of the aerosols for beta 2-adrenergic agonists in patients with severe airflow obstruction is approximately 3 μm. According to the instructions for the vibrating mesh nebulizer systems, Aeroneb can generate aerosols with a mass median aerodynamic diameter of 3.4 μm. Studies have shown that vibrating mesh nebulizers are more efficient for drug delivery compared with jet or ultrasonic nebulizers during mechanical ventilation [9]. In this case, several advantages of the vibrating mesh nebulizer helped to quickly deliver adequate quantities of procaterol to the lungs through a ventilator circuit to relieve bronchospasm after other medical treatments failed.

4. Conclusions

In conclusion, we experienced the treatment of a patient with severe asthmatic symptoms due to Yokkaichi asthma. Inhalation of procaterol using vibrating mesh nebulizer systems was effective against intractable respiratory failure with obstructive and restrictive lung disease patterns.

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