A pediatric case of life-threatening asthma managed with sevoflurane, intrapulmonary percussive ventilation and prone positioning

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Abstract: We describe a pediatric case of life-threatening asthma refractory to conventional therapies in which sevoflurane enabled adequate mechanical ventilation. However, despite improved peak inspiratory pressures, secretion retention and poor oxygenation remained. The combined use of intrapulmonary percussive ventilation (IPV) and prone positioning (PP) was effective in improving these manifestations. The use of inhalational anesthetics combined with IPV and PP may have life-saving effects in cases of life-threatening asthma.

Key words: ① life-threatening asthma, ② intrapulmonary percussive ventilation, ③ prone position

Case Report

A 4-year-old girl (weight, 24 kg) with an unremarkable medical history was admitted after experiencing her first asthma attack. She was orthopneic and drowsy. A physical examination revealed absent breath sounds bilaterally. Her vital signs were as follows: BP 68/30 mmHg, HR 160 ~170/min, and respiratory rate 70 ~80 /min. A chest radiograph revealed subcutaneous emphysema and pneumomediastinum (Fig. 1). The initial management included inhaled salbutamol, aminophylline, and systemic corticosteroids (Fig. 2). No response was noted and the subsequent use of isoproterenol via continuous nebulization was also ineffective.

She was transferred to the ICU 24 hr after initial presentation and was immediately intubated. The profile of her clinical course in the ICU is shown in Fig. 2 and Table 1. Upon admission to the ICU, peak inspiratory pressure (PIP) of 52 cmH2O was required in order to achieve tidal volumes of 3 ~4 ml/kg under pressure-controlled ventilation. The patient was administered sevoflurane via the Ohmeda 7900 Anesthesia Ventilator (Datex-Ohmeda, USA) within 30 min of ICU admission. Sevoflurane was initially administered at an inspired concentration of 3.0% and was titrated to between 0.8 and 1.5% based on clinical signs and PIP. Within minutes, her tidal volumes increased to 7.5 ml/kg, and the PIP reduced to 37 cmH2O. Although the sBP was 56 mmHg on ICU admission, it rose above 100 mmHg after sevoflurane therapy was initiated. Because patient-ventilator dyssynchrony was observed, vecuronium was administered continuously until ICU day 2.

After stopping vecuronium, sedation levels were monitored clinically to maintain sluggish response to loud auditory stimulus. Three hours after initiation of sevoflurane therapy, we suspected that the distal airways were retaining large amounts of secretions. The use of percussion, postural drainage, and humidification, endotracheal suctioning failed to remove the secretions. Intrapulmonary percussive ventilation (IPV) using IPV®-1C (Percussionaire®, USA) was applied to facilitate secretion removal. The anesthesia circuit was disconnected and the adapter of the IPV ventilator was attached directly to the tracheal tube. Sevoflurane was discontinued and salbutamol was administered by inhalation during IPV. The initial settings were as follows: frequency 250 /min and peak pressure 25 cmH2O. After IPV, a large quantity of secretion was removed via suctioning and the tidal volumes increased. The patient underwent IPV sessions for 10 ~20 min, 4 times daily, until extubation. Her oxygenation status still remained poor.

Prone positioning (PP) was employed in order to improve oxygenation on ICU day 2. She was returned to the supine position after remaining prone for 90 min. No adverse events were observed during PP and repositioning. Prone positioning improved the patient’s oxygenation status, and FIO2 successfully decreased. Thereafter, PP was implemented twice daily. A chest radiograph obtained on ICU day 3 revealed no pneumomediastinum (Fig. 1b). On ICU day 3, cessation of sevoflurane administration was tried on the basis of the improved respiratory profile, i.e., P/F ratio >200 was achieved with PIP
### Table 1  Arterial blood gas and ventilator settings

|                          | PaCO₂ (mmHg) | P/F ratio | PIP (cmH₂O) | PEEP (cmH₂O) |
|--------------------------|--------------|-----------|--------------|--------------|
| Before sevo/f_lurane therapy (day 1) | 58.2         | 65.8      | 52           | 12           |
| During sevo/f_lurane therapy (day 1)   | 56.6         | 164.6     | 37           | 12           |
| After IPV (day 1)               | 48.9         | 167.8     | 37           | 12           |
| Before PP + IPV (day 2)         | 44.0         | 107       | 37           | 7            |
| After PP + IPV (day 2)          | 56.7         | 234       | 30           | 5            |

IPV, intrapulmonary percussive ventilation; PIP, peak inspiratory pressure; PP, prone positioning.
<30 cmH₂O.

However, she had a relapse of bronchoconstriction within 30 min of cessation trial. The cessation trials were performed at least once per day, but every trial was abandoned until ICU day 8 because of continued relapse. Sevoflurane was successfully stopped on ICU day 9. The total duration of sevoflurane inhalation amounted to 172 hr. The patient was extubated on ICU day 19 and discharged home 6 weeks later, when her asthma was confirmed to be clinically stable. Informed consent for all the treatment maneuvers was provided by her parent.

Discussion

The mainstay approaches for treating severe asthma include bronchodilators and anti-inflammatory drugs. Inhalational anesthetics have bronchodilating effects and have been reported as a rescue therapy in life-threatening asthma. Inhalational anesthetics in life-threatening asthma remains unclear, some case series have suggested the efficacy of isoflurane in pediatric life-threatening asthma. The goals of mechanical ventilation for life-threatening asthma are to maintain adequate oxygenation and to minimize auto-PEEP and dynamic hyperinflation while limiting peak airway pressures and tidal volumes. Sevoflurane was successfully stopped on ICU day 9. The total duration of sevoflurane inhalation amounted to 172 hr. The patient was extubated on ICU day 19 and discharged home 6 weeks later, when her asthma was confirmed to be clinically stable. Informed consent for all the treatment maneuvers was provided by her parent.

Ventilation-perfusion (V̅A/Q̅) mismatching has been shown to be the fundamental mechanism underlying hypoxemia in asthma. In this case, sevoflurane and IPV failed to enhance oxygenation. It is speculated that residual bronchostenosis and secretions were the underlying mechanisms responsible for the persistent V̅A/Q̅ mismatching. It has been reported that PP decreases ventilation defects caused by bronchostenosis. The reported complications associated with PP include hemodynamic instability, desaturation, and inadvertent extubation. PP appeared to produce a sustained improvement in oxygenation without any complications in this case.

It is suggested that inhalational anesthetics can cause hypotension and neurocognitive impairment. Hypotension can result through vasodilatory effects of inhalational anesthetics. However, the hypotension observed on ICU admission was mitigated with sevoflurane therapy in our patient, presumably because the vasodilation was resolved by the improved venous return associated with mitigation of auto-PEEP and dynamic hyperinflation. Additionally, it is reported that prolonged exposure to inhalational anesthetics in early childhood may be associated with long-term impairment of neurocognitive function. Thus, once inhalational anesthetics are administered, it is crucial to avoid unnecessary anesthetic exposure.

Conclusion

Sevoflurane acts as a life-saving bronchodilator in the early phases of life-threatening asthma; however, secretion retention and poor oxygenation may remain. Under such circumstances, IPV and PP may provide beneficial effects to improved secretion removal and oxygenation, respectively.

Conflict of interest

The authors have no conflicts of interest to declare.

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