Hypercapnia in a patient with acute asthma is an ominous prognostic sign. In the past, it was taught that eucapnia in patients with acute severe asthma merited readiness for endotracheal intubation because the eucapnia might indicate a patient in transition from hypocapnia to hypercapnia. Although intubation and mechanical ventilation can be lifesaving in patients with acute severe asthma, these interventions are associated with great risks.

Intubation of an air-hungry patient with acute severe asthma can be difficult and may require use of sedatives and neuromuscular blocking agents, drugs that may produce apnea. Patients in unstable condition with tachypnea become patients in unstable condition with apnea and no patent airway. Once the trachea is intubated, airway resistance increases because of the geometry of the endotracheal tube and perhaps because of reflex bronchospasm caused by the introduction of this foreign body into the airway. Mechanical ventilation of patients with acute asthma can be difficult, requiring restraint in ventilator settings (permissive hypercapnia) to avoid barotrauma and hemodynamic depression associated with dynamic hyperinflation.

Heliox is a mixture of helium and oxygen that reduces airway resistance. We report rapid, marked improvement in the blood gases of a child with acute severe asthma and hypercapnia who breathed heliox while preparations for intubation were being made.

**Case Summary**

A 12-year-old girl with a history of asthma came to the emergency department because she had acute shortness of breath and wheezing associated with an upper respiratory tract infection. Her only asthma medication was albuterol as needed; montelukast therapy had been stopped 2 weeks earlier. Despite 3 back-to-back treatments with nebulized albuterol and ipratropium, she remained symptomatic and was admitted to the hospital. Intravenous administration of methylprednisolone was started in the emergency department.

Despite continued bronchodilator and corticosteroid therapy, the patient’s condition worsened, and she required increasing amounts of supplemental oxygen. A sample of blood for arterial blood gas analysis was obtained while she breathed oxygen via a simple face mask at a rate of 12 L/min. The results were as follows: pH 7.23; PaCO₂ 61 mm Hg; and PaO₂ 84 mm Hg. The patient was lethargic, was breathing at a rate of 60 to 70 breaths per minute, had tachycardia, and had pulsus paradoxus as indicated by pulse oximetry. Her chest was quiet on auscultatory examination.

While preparations for intubation were being made, she was given heliox from a premixed H-cylinder (80% helium, 20% oxygen) via a nonrebreather mask at a rate of 10 L/min, as indicated by an oxygen flowmeter (actual flow, 18 L/min). Nasal administration of oxygen at a rate of 2 L/min was required to keep her oxygen saturation greater than 90%. Arterial blood gas analysis of a blood sample obtained 25 minutes after the initiation of heliox revealed the following: pH 7.36, PaCO₂ 46 mm Hg, and PaO₂ 57 mm Hg. Plans for intubation were put on hold, and intensive pharmacological therapy continued, including intravenous terbutaline.

Frequent treatment with nebulized bronchodilators was given via a sidearm port of the nonrebreather mask; the nebulization was powered by heliox gas at a flow rate of 6 L/min from a second oxygen flowmeter (actual flow, 11 L/min), as suggested by Hess et al. The patient had progressive improvement in vital signs, level of consciousness, and oxygenation. After 5 hours of heliox therapy, she was returned to breathing a mixture of nitrogen and oxygen. She continued to improve, and she was discharged from the hospital 2 days later.
Discussion

Status asthmaticus is characterized by increased airway resistance, pulmonary hyperinflation, and increased dead space. All of these factors lead to increased work of breathing. If treatment with bronchodilators and corticosteroids does not reduce work of breathing quickly enough, ventilatory failure can occur. Airway resistance is increased by turbulent gas flow. The Reynolds number equation states that turbulent flow is created by higher gas velocity, gas density, and tube radius and lower gas viscosity. Because helium has a lower density and a higher viscosity than nitrogen and oxygen do, breathing heliox can convert turbulent flow into laminar flow, thereby decreasing airway resistance and work of breathing. Heliox is a unique therapy for acute asthma because it decreases airway resistance without changing the diameter of the airway.

Heliox-oxygen therapy for acute asthma was first described by New York physician and respiratory therapy pioneer Alvan Barach in the 1930s. When patients with acute severe asthma breathe heliox, peak expiratory flow rate (PEFR), work of breathing, and dyspnea can improve. Whether or not heliox has a role in the treatment of patients with acute asthma has been the subject of some debate.

Shiue and Gluck reported the results of heliox treatment in 10 patients with acute asthma and respiratory acidosis. Acidosis improved within 20 minutes, and none of the 10 patients required intubation. Kass and Castriotta reported the effect of heliox in 12 patients with acute asthma and hypercapnia. Of the 12 patients, 7 were receiving heliox by face mask. Overall, PaCO2 decreased, and only 2 of the 7 patients required intubation. In that study, patients who had had symptoms for less than 24 hours before treatment responded better to heliox than did patients who had symptoms longer. Indeed, both of the patients who eventually required intubation had experienced symptoms for more than 4 days.

A randomized, controlled trial of heliox in children with status asthmaticus showed that breathing heliox reduced pulsus paradoxus and dyspnea and increased PEFR. For 3 children in the heliox group, breathing heliox averted planned intubation. Kass and Terregino reported similar improvements in PEFR and dyspnea in a randomized, controlled trial of heliox in adults with asthma.

Some research results do not support the use of heliox in the treatment of acute severe asthma. Carter et al did a randomized, crossover study of treatment with heliox in 11 children hospitalized with acute asthma. All children were treated with albuterol and methylprednisolone and were randomized to breathe heliox (70% helium and 30% oxygen) or 30% oxygen for 15 minutes. The 2 groups had no clinically significant difference in spirometric data or dyspnea. Of the 11 children, 2 were not enrolled in the study until days 2 and 3 of hospitalization because they were too ill, presumably too dyspneic, for spirometry to be performed on the day of admission to the hospital. Perhaps these 2 children would have had a more impressive clinical response to heliox on hospital day 1 when they were experiencing more dyspnea and probably had a greater degree of turbulent flow. Verbeek and Chopra also reported no improvement in forced expiratory volume in 1 second in patients with acute asthma after the patients breathed heliox for 5 minutes; however, PEFR may be more affected by a reduction in turbulence than is forced expiratory volume in 1 second.

Research findings do not support the routine use of heliox therapy for patients with acute severe asthma. For these patients, simply improving PEFR and dyspnea does not mean that outcomes will be sufficiently affected to warrant the additional cost and effort of using heliox, because most of the patients respond to conventional therapy. However, in patients with acute hypercapnia, heliox may help reduce the need for intubation by unloading the respiratory muscles, improving ventilation, and allowing more time for corticosteroid therapy to take effect. In one reported case, heliox was a tremendous tool to have available because the patient, who had severe asthma and hypercapnia, refused intubation.

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Use of Heliox to Avoid Intubation in a Child With Acute Severe Asthma and Hypercapnia
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Am J Crit Care 2003;12 28-30
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