AVOIDING INTUBATION IN THE INJURED SUBGLOTTIS: THE ROLE OF HELIOX THERAPY

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Intubation in the child presenting with severe viral tracheobronchitis or prior subglottic injury can be detrimental to the child and the subglottis. Intubation may lead to further mucosal ischemia, scar, subglottic stenosis, or failed extubation requiring a tracheotomy. Heliox is a combination of helium and oxygen that produces less-dense gas exchange. Its use leads to a decrease in turbulent airflow, which may obviate the need for intubation. Here we report our experience using heliox as initial therapy in 14 consecutive children presenting with severe airway distress and the need for intubation. (Five had viral tracheobronchitis, 5 had inflammatory exacerbation of subglottic stenosis, and 4 had acute iatrogenic subglottic injury.) In 10 of the 14 children, intubation, which can lead to mucosal injury and scarring, was avoided by the use of heliox therapy. Of the 4 children in whom heliox therapy failed, 3 had a prior history of subglottic stenosis. Heliox is a relatively safe and reliable alternative to intubation of children with severe subglottic edema or injury. Heliox should be considered before intubation for selected children with subglottic inflammation and severe airway distress.

KEY WORDS — heliox, subglottic stenosis, viral tracheobronchitis.

INTRODUCTION

Heliox is a gas mixture composed of helium and oxygen. Its use in upper airway obstruction was first suggested in 1934.[1] In spite of its introduction more than 60 years ago, it has never seen widespread clinical use. Heliox has a density one third that of room air, and it is this property that makes it useful in the treatment of airway obstruction. Heliox decreases resistance to flow, changes turbulent flow to laminar flow, and promotes the diffusion of carbon dioxide and thereby decreases the work of breathing.[2-7] Ultimately, these advantages may obviate the need for intubation. Intubation can be detrimental to the upper airway, including the subglottis, where it may lead to further mucosal injury or scar.[8] We present 14 consecutive pediatric patients who developed severe respiratory distress that failed to resolve with conventional medical treatment who were subsequently treated with heliox. Our goal was to determine whether endotracheal intubation could be avoided through the use of heliox.

MATERIAL AND METHODS

Patients who had presented to Wake Forest University Baptist Medical Center–Brenner Children's Hospital in severe respiratory distress due to an upper airway lesion were initially treated with conventional medical therapy consisting of humidified oxygen, intravenous steroids, and nebulized racemic epinephrine bitartrate. Heliox was used in 14 consecutive patients in whom this treatment failed and in whom intubation or reintubation was impending. Five of the patients had a primary diagnosis of viral tracheobronchitis, 5 had an inflammatory exacerbation of underlying subglottic stenosis, and 4 had an acute traumatic injury to the subglottis. All of the patients were initially treated with commercially prepared heliox composed of 70% helium and 30% oxygen. Although heliox does not have approval from the US Food and Drug Administration for this indication, it has been used in our institution without any side effects. The heliox was delivered by either an oxyhood or a non-rebreather face mask, or through a continuous positive pressure mask. In children in whom heliox treatment was successful, the patient was subsequently weaned to humidified oxygen without helium.

RESULTS

We present 2 representative case reports, followed by a summary of our 14 cases.

Case 1. A 4-month-old girl presented to an outside hospital with a 5-day history of noisy breathing. The diagnosis made was bronchiolitis. She was subsequently released and referred as an outpatient to our institution. The patient's medical history was significant for intrauterine growth retardation, as well as respiratory distress at birth that required intuba-

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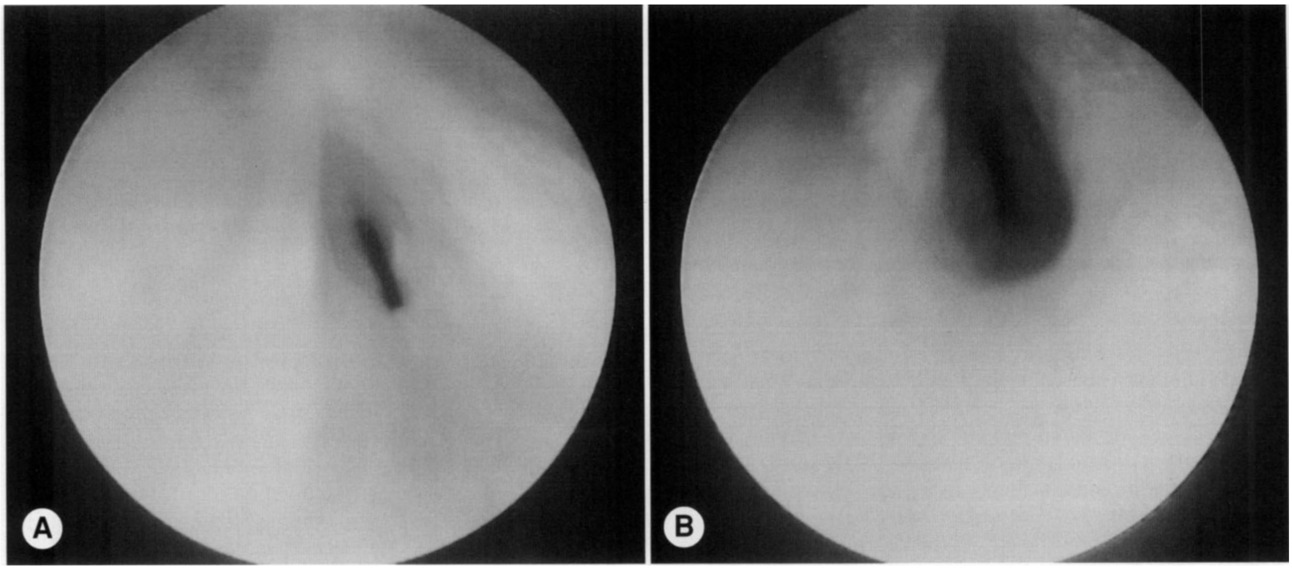

Fig 1. (Case 1) Findings at endoscopy. **A)** Glottis and subglottis. **B)** Closer view of subglottis.

tion. The patient's initial examination revealed biphasic stridor and mild retractions. A further review of the history revealed a choking spell prior to the onset of the noisy breathing. In view of the possibility of foreign body aspiration, it was decided to take the patient to the operating room, where she underwent direct laryngoscopy and bronchoscopy. This procedure revealed severe subcordal edema that extended into the subglottis (Fig 1). On the first postoperative day, the patient developed respiratory distress requiring intubation. It was believed that the patient's respiratory distress was due to postbronchoscopy edema on top of the existing subglottic edema. After extubation, the patient developed respiratory distress that failed to resolve with intravenous steroids, racemic epinephrine, and humidified oxygen. The patient was placed on heliox via a non-rebreather mask, which she tolerated well. The patient remained on heliox for a period of 24 hours, after which time she was successfully weaned to room air.

Case 2. A 2-month-old boy with a 2-day history of stridor, croupy cough, and fever to 41°C (106°F) presented to an outside hospital emergency department. On arrival, he developed cardiopulmonary arrest. The patient was intubated with an uncuffed 4.5-mm (internal diameter) endotracheal tube, resuscitated, and transferred to our institution for further evaluation and treatment. Examination in the pediatric intensive care unit revealed blood in the endotracheal tube suggestive of traumatic intubation. The patient's endotracheal tube was immediately downsized to a 3.0-mm (internal diameter) tube. The patient was taken to the operating room, where he underwent direct laryngoscopy and bronchoscopy that revealed extensive subglottic edema and mucosal ischemia (Fig 2). He remained intubated for 9 days while his medical condition stabilized. After extuba-

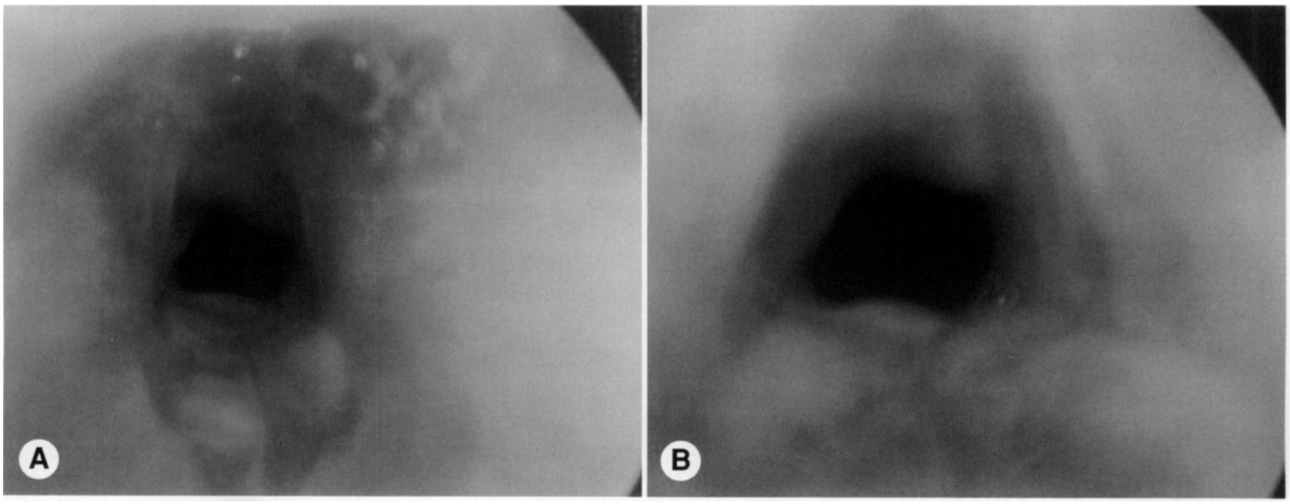

Fig 2. (Case 2) Findings at endoscopy. **A)** Glottis and subglottis. **B)** Closer view of subglottis.

PATIENT DATA

Age	Airway Diagnosis	Route of Heliox Delivery	Duration of Heliox Use	Intubation Avoided
4 mo	Subglottic stenosis	Oxyhood	24 h/6 d*	On second attempt
1 mo	Subglottic stenosis	Oxyhood	4 d	Yes
3 y	Tracheo-bronchitis	CPAP	2 d	Yes
2 y	Traumatic injury	Face mask	4 d	Yes
7 mo	Traumatic injury	Oxyhood	36 h	Yes
2 mo	Subglottic stenosis	Oxyhood/ CPAP	36 h	No
2 mo	Tracheo-bronchitis	Oxyhood	4 d	Yes
1 mo	Subglottic stenosis	CPAP	3 d	Yes
3 mo	Traumatic injury	Face mask	36 h	Yes
1 mo	Tracheo-bronchitis	Oxyhood	4 d	Yes
2 y	Tracheo-bronchitis	Face mask	36 h/12h*	On second attempt
2 mo	Traumatic injury	Oxyhood	36 h	Yes
3.5 mo	Subglottic stenosis	Face mask	24 h	No
2 y	Tracheo-bronchitis	Face mask	20 h	Yes

CPAP — continuous positive airway pressure.

*For patients in whom heliox therapy initially failed but who were subsequently extubated by means of heliox, both treatment intervals are given.

tion, he developed respiratory distress that failed to resolve with medical treatment. Heliox was successfully instituted, and reintubation was avoided. The patient was successfully weaned to room air after 36 hours of treatment.

Of the 14 patients in whom heliox therapy was implemented, intubation or reintubation was avoided in 10 (see Table). Of the 4 patients who required airway intervention, 2 were subsequently successfully extubated with the use of heliox. The duration of heliox therapy ranged from 20 hours to 6 days. In several patients, as the heliox was discontinued, the stridor and respiratory distress returned, requiring reinitiation of the heliox therapy. In these patients, once the underlying upper airway disorder improved, heliox was successfully discontinued. In the 2 patients in whom the heliox was ultimately unsuccessful, there was evidence of tongue base obstruction. Three of the 4 patients in whom heliox therapy initially failed had severe underlying subglottic stenosis, and 2 of them eventually required tracheotomy.

Fig 3. Patient undergoing heliox therapy in which gas mixture is delivered via oxyhood.

DISCUSSION

The use of heliox in airway obstruction was first described by Barach[1] in 1934. Its use was limited by military demand during World War II, and it never gained widespread use.[9,10] Heliox is available commercially in concentrations of 70% to 80% helium combined with 20% or 30% oxygen. Additional oxygen can be added from a separate source. However, as the concentration of helium is decreased, it may lose its advantageous properties.[11] It can be delivered through a non-rebreather face mask or a continuous positive airway pressure mask, or via an oxyhood (Fig 3).

Heliox has been used in multiple clinical settings. The literature includes case reports of its use in respiratory distress syndrome, postextubation stridor, asthma, chronic obstructive pulmonary disease, croup, bronchiolitis, and primary airway tumors.[4,5,12-16] It has also been used to facilitate ventilation during flexible bronchoscopy, in cases in which the bronchoscope is close to the diameter of the endotracheal tube it is inserted through.[17] Interestingly, despite its particular applicability to upper airway obstruction, an extensive literature search revealed no case reports in the otolaryngology literature.

Heliox has multiple advantages over room air and oxygen. It decreases the resistance to airflow, converts turbulent flow to laminar flow, increases the diffusion of carbon dioxide, decreases the work of breathing, and ultimately may obviate the need for intubation.[2-7] These advantages are derived from the fact that helium has a density one seventh that of nitrogen, and heliox has a density one third that of room air.

As previously stated, heliox converts turbulent flow to laminar flow. It takes substantially less pressure to drive a gas under conditions of laminar flow than it does under turbulent flow. Whether flow will be turbulent or laminar is determined by Reynolds' number. Reynolds' number is calculated from the formula $Re = 2rvd/\eta$ where Re = Reynolds' number, r = radius, v = velocity, d = density, and η = viscosity. Reynolds' numbers of less than 2,000 are associated with laminar flow. Gases with lower densities will have a lower Reynolds' number and will be more likely to course through the airway under conditions of laminar flow.

In cases in which flow remains turbulent, heliox continues to have a beneficial role in decreasing resistance. During conditions of turbulent flow, the driving pressure is directly proportional to the density of the gas and inversely proportional to the fifth power of the radius. Although resistance during turbulent flow varies depending on the rate of flow, it is directly related to the density of the gas. Experiments that have examined the decrease in resistance to flow of heliox relative to room air report a 20% to 40% reduction in resistance, depending on the respiratory rate and the disease process in question.[3,6,7]

Heliox also increases the diffusion of carbon dioxide. Carbon dioxide diffuses 4 to 5 times faster in heliox than in room air.[18] In patients with hypercarbic respiratory failure, this offers a significant advantage. The decrease in the partial pressure of carbon dioxide may be associated with an improvement in respiratory acidosis, a quality that has also been ascribed to heliox.[17-20]

Heliox has also been found to decrease the work of breathing. In 1983, Skrinskas et al[4] determined that breathing heliox at a respiratory rate of between 24 and 36 breaths per minute was associated with a 31% to 36% decrease in the work of breathing. This decreased work of breathing also results in decreased carbon dioxide production and oxygen consumption.[5] In pediatric patients, the trachea is particularly pliable. The decreased intrathoracic pressures generated during heliox use may be associated with decreased tracheal collapse and less dynamic narrowing of the airway.[15]

Ultimately, heliox may obviate the need for intubation. In 4 of the patients in our series, intubation trauma was the primary cause of the airway distress. In 3 additional patients, it may have been a contributing factor in the increase in subglottic inflammation. Intubation may also lead to further mucosal ischemia, injury, scar, and subglottic stenosis.[8] In this study, 10 of the 14 patients did not require intubation after the institution of heliox therapy. Of the 4 remaining patients, 2 were subsequently extubated with the help of heliox. Of the 4 patients in whom heliox therapy initially failed, 3 had significant underlying subglottic stenosis. The 2 patients in whom subsequent extubation attempts failed had tongue base obstruction, which contributed to their airway distress.

Heliox is an inert gas that is near-insoluble in tissue and is nonreactive with biological membranes. As a result, there are few complications reported in the literature. In our series of 14 patients, there were no observed side effects. Two reported side effects are hypothermia and hypoxemia.[12,21] The hypothermia relates to the thermal conductivity of helium, which is 4 to 6 times greater than that of nitrogen.[10] Warming of the inspired gas mixture should prevent this potential complication from occurring. Hypoxemia may be related to the diminishing benefit of heliox as the oxygen content is increased and the helium content is decreased.[11]

CONCLUSIONS

Heliox may be an important adjunct to the medical treatment of upper airway obstruction. It may serve as a temporizing agent to allow for the natural resolution of the disease process. The use of heliox should be considered selectively in children with subglottic inflammation and respiratory distress.

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