Abstract

Objective: to demonstrate the effectiveness and the positive outcome of patients treated with helium-oxygen (heliox) mixture. Heliox has been used in patients with airway obstruction of different etiologies who do not respond to a conventional treatment with oxygen.

Methods: report of four cases of patients who received heliox as treatment for airway obstruction. All of them presented good results, presenting almost no side effects during the treatment.

Conclusion: Heliox is a promising treatment for severe airway obstructions, presenting positive outcomes in a short period of time, until the final treatment is established.

Introduction

The use of the helium-oxygen mixture (heliox) in cases of airway obstruction of different etiologies has become increasingly frequent, presenting satisfactory results and being virtually free from side effects.

Heliox promotes a greater diffusion of oxygen through the airways, resulting in clinical and laboratory improvements within a short period of time, due to its low density and to the fact that it does not combine with active membranes.

This report was divided according to the airway anatomy and their respective pathologies. In all reviewed cases, the authors showed excellent results treating their patients with heliox.

Case 1

SH, female, 16 years old, presenting cerebral palsy, admitted with aspiration pneumonia. Thoracic X-ray showed opacification of the entire right lung.
The patient was admitted to the children’s intensive care unit with important respiratory effort, RR = 52/min, PCO₂ = 65 mmHg, and intercostal recession; the case evolved to respiratory failure, and required endotracheal intubation (for 4 weeks) and venous therapy with antibiotics.

After the extubation, the patient presented important inspiratory stridor, and then she began to receive continuous nebulization with racemic epinephrine and venous corticoid; there was very little improvement in the clinical status. The patient remained presenting respiratory effort, with RR = 35-42/min and PaCO₂ = 56-62 mmHg.

We introduced heliox at 70/30 (70% helium : 30% oxygen) with an inhaling mask. Clinical and laboratory improvement occurred approximately 30 minutes later, with a decrease in the respiratory effort (RR = 22-25/min), and an improvement in hypercapnia (PaCO₂ = 40-45 mmHg). Heliox was raised to 80/20 (80% helium : 20% oxygen), and administered for 48 hours. After suspending heliox, the patient was released from the intensive care unit.

Case 2

DB, male, 3 months old. The patient presented history of prematurity and bronchopulmonary dysplasia.

Four days prior to admission, the child developed a viral status, presenting nasal obstruction, respiratory distress, and laryngeal stridor; this status had worsened during the last 24 hours. We collected material from the oral and nasal cavities for culture. The assessment was positive for respiratory syncytial virus.

We started nebulization with racemic epinephrine, but the patient did not respond. The child continued with respiratory effort, intercostal recession and nasal flaring. Laboratory exams presented arterial gasometry with acidosis, hypercapnia, and low saturation (Ph = 7.29, PaCO₂ = 65 mmHg, PaO₂ = 70 mmHg, O₂ Sat = 65-70%); so, mechanical ventilation was required at FiO₂ 0.7. The patient presented a slight improvement in hypercapnia; however, the low saturation (80%) remained unchanged. We introduced heliox at 60/40 through mechanical ventilation, obtaining improved Ph (7.38), decreased PCO₂ (40 mmHg), and improved saturation (92%) in 1 hour. The patient remained intubated for 7 days. After extubation, he received 80/20 heliox with an inhaling mask for 72 hours, without complications. The patient was released from the intensive care unit 24 hours after the interruption of the use of heliox.

Case 3

MT, 10 years old, male, consciously asthmatic since the age of 6, presenting a status of cough, mucus production, and wheezes for 1 week. Twenty-four hours prior to admission, the patient began to present symptoms of respiratory distress and tiredness. He had been using albuterol three times a day, and Atrovent twice a day for 1 month. The patient was directed to the emergency room, where he presented an 80% oxygen saturation in 100% of O₂ with a mask, RR = 60/min, gasometry displaying Ph = 7.41, PO₂ = 37 mmHg, PCO₂ = 65 mmHg, HCO₃⁻ = 23 meq/l, and BE = -1.2 meq/l. The child received standard medication for the treatment of asthma, but did not show improvement. Then, the patient was intubated and transferred to children’s intensive care unit. Thoracic X-ray showed hyperinflation and atelectasis at the left upper lobe. The patient remained stable, did not present any improvement. Terbutaline was then administered, as well as a continuous nebulization with albuterol, magnesium sulfate, and two doses of ketamine. Solumedrol and aminophylline were kept. Later, a transfer to the medical center of the University of California was solicited, so that the child could receive better care.

The patient was admitted to this service presenting a severe clinical status, with rare wheezes and great ventilatory difficulty. He presented hypocalcemia and a decrease in bicarbonate - both were corrected. Since his glucose level was high (375 mg/ml), he received a dose of insulin. He was kept in continuous sedation, receiving dopamine, cefuroxime (computed tomographic scan showed sinusitis, with an increased production of mucus), and 60/40 heliox (60% helium : 40% oxygen) through mechanical ventilation to improve gas exchanges, thus decreasing PaCO₂. Initial gasometry indicated Ph = 7.18, PaCO₂ = 74 mmHg, PaO₂ = 70 mmHg, HCO₃⁻ = 27 meq/l, BE = -3 meq/l, and O₂ Sat = 80%. Fifteen minutes after the administration of heliox, gasometry showed Ph = 7.32, PaCO₂ = 35 mmHg, PaO₂ = 58 mmHg, HCO₃⁻ = 25 meq/l, BE = +2 meq/l, and O₂ Sat = 93%.

The patient was kept intubated for 36 hours. After extubation, he received 75/25 heliox, with an inhaling mask during 12 hours. Later, he was dismissed from the intensive care unit.

Case 4

CB, female, 7 years old, consciously asthmatic. She was admitted to the hospital’s emergency room with a history of respiratory distress, cough and wheeze for the previous 24 hours. On physical exam, the patient presented RR = 60/min with the use of accessory respiratory muscles, accentuated wheezes, and pulse oxymetry at 80% in room air.

The initial therapy was albuterol and venous methylprednisone at 2 mg/kg; nebulization was continually administered with albuterol at 0.6 mg/kg/h, and methylprednisone dose at 1 mg/kg 6/6 h. Arterial gasometry presented Ph = 7.3, PCO₂ = 50 mmHg, PO₂ = 60 mmHg, HCO₃⁻ = 25 meq/l, BE = -2 meq/l, and Sat = 78%.

The child was transferred to the pediatric intensive care unit for continuous monitoring and to begin therapy with 60/40 heliox (60% helium : 40% oxygen).
The patient started to receive nebulization with albuterol in the heliox mixture, instead of the standard oxygen and nitrogen. After 30 minutes using heliox, a considerable improvement was noticed in the respiratory frequency rate, which fell to 30-35/min, and in the gasometry, which presented pH=7.35, PCO$_2$=38mmHg, PO$_2$=65mmHg, HCO$_3$=23meq/l, BE=0meq/l, and Sat=92%.

The patient received heliox for 24 hours, and did not require mechanical ventilation. She was held in the intensive care unit for more than 24 hours, and then she was dismissed to the ward. Dismissal occurred after 24 hours.

Comments

Helium is a biologically inert gas of low molecular weight. It is insoluble in tissues at 1 atmosphere, and it does not react with biological membranes.\(^1\)

Helium was discovered in 1895 by Ramsey, and later introduced to the medical community by Barach, in 1935, aiming at treating airway obstruction.\(^2\,\,3\)

The main therapeutic property of helium is its low density (0.179 micropoise) - compared with 1.293 of the air and, 1.429 of oxygen. Due to this low density, helium is used to facilitate gas flow in narrow orifices.\(^4\)

Reynolds’s number, defined as \(\text{Re}=\text{pdV}/\text{m}\), indicates turbulent flow when the result goes over 2,000. In this equation, \(\text{p}\) indicates the density of the gas, \(\text{d}\), the diameter, \(\text{v}\), the linear velocity of the gas, and \(\text{m}\), the gas viscosity.

According to Reynolds’s number, the proportion between kinetic power and viscosity indicates whether the flow is laminar or turbulent. Turbulent flow is said to occur when the result of this equation is higher than 2,000. Helium acts reducing the gas flow resistance if compared to air or oxygen,\(^5\) since it is known that helium increases laminar flow and decreases turbulent flow due to its low density. In the absence of turbulent flow, helium improves flow and decreases the effort to breathe wherever an airway obstruction is found.\(^6\,\,\,9\)

In medicine, helium is used in association with oxygen; therefore, the final density will depend on the percentage of both gases. The 80/20 heliox mixture (80% helium and 20% oxygen) has a final density of 0.429 micropoise. This mixture will be the least dense, and thus the one providing the greatest reduction in airflow resistance.\(^10\,\,\,12\)

The breathing of 70/30 heliox mixture presents a lower flow resistance than the breathing of any concentration of oxygen (in nitrogen), including a FiO$_2$ of 1.\(^13\) The use of heliox in concentrations inferior to 60/40 has not been demonstrating a satisfactory therapeutic effect due to its high density.\(^14\,\,15\)

Helium is mainly used in cases of upper airway obstruction. Syrinskas et al.\(^21\) demonstrated the use of heliox in ten patients with upper airway obstruction of different etiologies, including endotracheal post-intubation

The use of heliox has demonstrated decrease in barotrauma, since the patient is ventilated with less volume and less pressure than in the conventional oxygen/nitrogen mixture. Heliox has also been used to improve the relation between ventilation/perforation, in order to equal both of them.\(^17\)

Side effects

Heliox, despite all the advantages presented, must be carefully used, since the low density may reduce lung volume and increase intrapulmonary shunts.\(^18\,\,19\)

Also, helium has a high thermal conductivity, four or five times higher than nitrogen. This may configure a risk for hypothermia when its temperature is below 36 ºC.\(^20\)

Heliox availability

Helium is available in tanks of several sizes. It costs approximately 15 times more than oxygen.

Helium can be connected to oxygen through an Y, providing the desired quantity of heliox by adjusting both gases. A ready-made mixture of these gases in a tank can also be found in different concentrations.

Helium must be moisturized and heated at body temperature so that the patient does not lose heat, since - as we mentioned before - helium has a high conductivity.

Patients can receive heliox either being intubated or not. In nonintubated patients, the mixture must be supplied to them in a way that the contact with room air is kept to a minimum, so that the mixture does not dilute. Patients may receive heliox by an inhaling mask, with a container for the mixture, unidirectional flow, and a small opening for releasing carbon dioxide. Patients may also receive heliox by a mask with continuous positive pressure.

In intubated patients, the helium tank must be connected in the place of the compressed air. In this case, the measure of FiO$_2$ will not be exact, since the ventilator is calibrated to receive air and oxygen. Oxygen must be controlled. The running volume will not be exact either, since the measure of the flow is set for oxygen and nitrogen, not for oxygen and helium.

In intubated patients, special attention must be given to the risk for thoracic expansion. Heliox rate must be high enough so that the total airflow is adequate to satisfy and exceed the minute volume needed by the patient.

Heliox in the respiratory tract

**Upper airways**

Heliox is mainly used in cases of upper airway obstruction. Syrinskas et al.\(^21\) demonstrated the use of heliox in ten patients with upper airway obstruction of different etiologies, including endotracheal post-intubation
subglottic edema (n=4), post-radiotherapy obstruction (n=3), and primary tumors of the airways (n=3). The result obtained by these authors with heliox was successful in nine out of the ten patients. The success of the treatment was based on clinical and laboratory improvements. Clinically, patients presented a decrease in the respiratory rate, ventilation and saturation improvement, and a decrease in the use of accessory muscles. Laboratory evaluation was based on improvement in $\text{PaO}_2$ and decrease in $\text{PaCO}_2$. Seven out of the ten patients included in the study did not need endotracheal intubation, due to their satisfactory response to heliox.

Duncan\(^{22}\) showed the efficacy of heliox as a temporary therapy in patients with respiratory distress caused by post-extubation or by a viral subglottic edema. Seven patients were in this situation. The evaluation of these patients was based on respiratory sounds, degree of stridor, cough, intercostal recession and cyanosis. Patients initially received the standard treatment with oxygen by a mask and racemic epinephrine, and did not present any response. Then, 80/20 heliox was introduced in replacement with oxygen and air. Patients presented a significant clinical improvement, with reduction of respiratory distress (7.9 +/- 0.4 to 3.9 +/- 0.3; P<0.001), and $\text{PaCO}_2$ decreased after the introduction of heliox. The results found in our services are similar to those observed in the literature, with a 90% success rate. One example of this is patient number 1, who presented a significant gradual improvement in a short period of time.

**Distal Airways (Trachea and Bronchi)**

Lu et al.\(^{24}\) demonstrated the successful use of heliox in a 49 year-old patient with bronchogenic squamous cell carcinoma, which led to an extrinsic obstruction. This patient was submitted to a right pneumectomy, and developed a condition that narrowed the left bronchial tree (4 mm in diameter).

During bronchoscopy, the patient progressively presented dyspnea, which evolved to respiratory failure, and required endotracheal intubation. Heliox was introduced at 70/30 (70% helium : 30% oxygen) through mechanical ventilation with progressive increase of pulmonary ventilation, volume, and peak of inspiratory pressure. The authors investigated these findings in an animal model. The study was performed with dogs of the Mongrel breed. Six dogs underwent a ligation of the right pulmonary artery and of the right lung. The left bronchial tree was partially occluded, but it did not cause hypoxemia or bradycardia.

Heliox was introduced at 20% (20% helium : 80% oxygen), and then gradually increased up to 80% (80% helium : 20% oxygen). Tidal volume or ventilatory time remained unaltered; however, a progressive decrease of the rates of peak of inspiratory pressure and $\text{PaCO}_2$ was observed while the percentage of helium was being increased. This change became statistically significant when the concentration of helium reached 60/80. The authors noticed that no hemodynamic alterations occurred in the studied animals, including cardiac index, mean arterial pressure, volume, and cardiac compromise.

Mizrahi et al.\(^{25}\) demonstrated the successful use of heliox in a 43 year-old patient presenting mediastinal Hodgkin’s disease compromising the airways by the enlargement of the hilar node. The authors noticed a significant improvement in this patient, whose rates of $\text{PaCO}_2$ decreased after the introduction of heliox. The mixture was used for 72 hours, and then the patient started to receive radiotherapy, with the eventual resolution of enlarged nodes and respiratory symptoms.

Tobias\(^{13}\) demonstrated a significant improvement in the respiratory function with the administration of heliox in a 4-month old child who presented anteroposterior obstruction of the trachea, which was extended up to the carina (tracheomalacia), with positive diagnosis for respiratory syncytial virus. This child was intubated and received 70/30 heliox through mechanical ventilation, presenting progressive improvement (clinical and laboratory), and being extubated 5 days later. The child received 60/40 heliox with an inhaling mask, and presented positive evolution of the clinical status.

The use of heliox in the treatment of children with distal airways is more restricted, since these pathologies are rare in this age group.

**Peripheral Airways (Bronchospasm)**

Bronchospasm causes decrease in ventilation and perfusion, leading to hypoxia caused by difficulty in gas exchanges.

The use of helium, due to its low density, converts turbulent flow into laminar flow; in the absence of turbulent flow, helium improves flow and decreases respiratory effort in the bronchoconstricted areas, facilitating gas exchanges. Helium improves the ventilation/perfusion ratio by equaling them.\(^{26,27}\)

Carbon dioxide is diffused four or five times faster in an heliox mixture than in conventional air and oxygen.\(^{28-30}\)

Several clinical studies have suggested the therapeutic efficacy of helium in patients with status asthmaticus, since it allows beta-2 and corticoid to have enough time to act.

Kudukis et al.\(^{31}\) studied 18 patients with status asthmaticus who were being treated with continuous
inhalation of beta-agonist and methylprednisone. In a double-blind study, these patients were randomized in two groups: ten were treated with heliox, and eight, with oxygen and air. Patients presented pulsus paradoxus greater than 15 mmHg.

In all patients, data included pulsus paradoxus, respiratory rate, cardiac index, dyspnea score, and oxygen saturation. These values were obtained during the intervention and 15 minutes after it. In some patients, peak flows were measured before and after receiving heliox or oxygen and air.

The observed results showed that pulsus paradoxus (in mmHg) fell significantly from an initial mean value of 23.3 +/- 6.8 to 10.6 +/- 2.8 in heliox breathing (P<0.001), and increased again to 18.5 +/- 7.3 after heliox was suspended.

Peak flow increased 69.4% +/- 12.8% during the use of heliox (P<0.05).

Dyspnea index decreased from a initial measure of 5.7 +/- 1.3 to 1.9 +/- 1.7 with heliox breathing (P<0.0002), and increased again to 4.0 +/- 0.5 after its cessation.

In control patients, there was no significant difference in pulsus paradoxus or dyspnea at any time during the study period.

Mechanical ventilation was averted in three patients breathing heliox, due to the improvement in dyspnea; these patients did not present side effects.

The authors concluded that during acute status asthmaticus, patients who inhaled heliox significantly decreased pulsus paradoxus, increased peak flow, and decreased the dyspnea index. Moreover, heliox reduced respiratory effort, prevented respiratory failure, and also the need for mechanical ventilation.

Kass et al. demonstrated the use of heliox in 12 patients with status asthmaticus and respiratory acidosis (pH<7.35 and PaCO2>45 mmHg). Five patients inhaled heliox through a ventilator, and seven received it via facemask. The therapeutic result with heliox was the decrease of PaCO2 from 57.9 mmHg +/- 8.3 to 47.5 mmHg +/- 4.3, and the increase of pH from 7.23 +/- 0.07 to 7.32 +/- 0.04, which promoted a significant clinical improvement in these patients.

Manthous et al. demonstrated that heliox improves expiratory flow and decreases pulsus paradoxus while studying 27 adults with status asthmaticus. In the control group, improvement in expiratory flow and decrease in pulsus paradoxus was also observed (using beta-agonist and corticoid), although a clinically significant improvement was noticed only among patients breathing heliox.

Gluck et al. studied the use of heliox in seven patients with status asthmaticus and respiratory acidosis who were receiving mechanical ventilation. These patients received a 60/40 mixture of heliox. All patients presented a reduction in airway pressure, in CO2, as well as resolution of acidosis while breathing heliox. The change of peak inspiratory pressure was early noticed (2.5 minutes), with a maximal fall of PaCO2 registered at 22 minutes.

The results presented by the cited authors are similar to those observed in our service, where, if the conventional treatment for status asthmaticus does not present clinical or laboratory improvement, a 60/40 mixture of heliox is introduced to assist the treatment. We obtain positive results in 85% of the cases, which has made it become a routine in our service, as we observed in patients number 3 and 4.

Anderson et al. evidenced that the deposition of medication particles in aerosol increases when a 50/50 mixture of heliox is administered, compared to room air. The authors concluded that the inhalation of drugs in heliox has a favorable effect on patients with severe obstructive disease of the airways.

Paret et al. attested in a case report that the use of heliox presents beneficial effect in the treatment of children with acute bronchiolitis secondary to respiratory syncytial virus. The use of heliox may prevent mechanical ventilation and reduce morbidity.

A similar result was observed in patient number 2. The use of heliox in patients with diagnosis of respiratory syncytial virus has shown a great clinical and laboratory improvement in these patients, as well as a better evolution of the disease.

Conclusion

The heliox mixture has been presented as a new option for patients who do not respond to conventional treatment with oxygen therapy.

Heliox should be used as a palliative measure for the treatment of airway obstruction of different etiologies.

Presenting a quick response by the patient, the function of helium is to work as a temporary solution in these cases, until a definitive treatment is established, or until a natural outcome of the disease occurs.

References


