Helium insufflation with sevoflurane general anesthesia and spontaneous ventilation during airway surgery

L'insufflation d'hélium lors d'une anesthésie générale au sévoflurane et avec ventilation spontanée pour une chirurgie des voies aériennes

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Abstract

Purpose *The therapeutic benefits and clinical applications of helium-oxygen gas mixtures were first reported over 70 years ago. Since then, helium has been used in the treatment of obstructive processes of both the upper and lower airways. We report a unique case regarding helium insufflation with sevoflurane anesthesia and spontaneous ventilation for airway surgery.*

Clinical features *A helium-oxygen mixture was administered during airway surgery in an 8-year-old boy with obstruction of the upper airway. Following the introduction of a helium-oxygen mixture during general anesthesia with spontaneous ventilation, a relatively rapid improvement in the patient's respiratory status was observed with a decrease in the audible inspiratory stridor, improved gas exchange, decreased respiratory rate, decreased suprasternal/intercostal retractions, and a decrease in the transcutaneous CO₂. The physiologic basis for helium's effects on gas exchange are discussed and its use during insufflation for upper airway surgery is reviewed.*

Conclusions *The addition of helium improves gas exchange with spontaneous ventilation during general anesthesia for airway surgery.*

Résumé

Objectif *Les bienfaits thérapeutiques et les applications cliniques des mélanges gazeux hélium-oxygène ont été*

rapportés pour la première fois il y a plus de 70 ans. Depuis, l'hélium a été utilisé dans le traitement de syndromes obstructifs des voies aériennes supérieures et inférieures. Nous rapportons ici un cas unique en ce qui touche à l'insufflation d'hélium lors d'une anesthésie au sévoflurane en ventilation spontanée lors d'une chirurgie des voies aériennes.

Éléments Cliniques *Un mélange hélium-oxygène a été administré pendant une chirurgie des voies aériennes réalisée chez un enfant de huit ans manifestant une obstruction des voies aériennes supérieures. Après l'introduction d'un mélange hélium-oxygène pendant l'anesthésie générale avec ventilation spontanée, une amélioration relativement rapide de l'état respiratoire du patient a été observée avec une diminution du stridor audible, un échange gazeux amélioré, une fréquence respiratoire réduite, un tirage suprasternal/intercostal moindre et une réduction du CO₂ transcutané. Le fondement physiologique des effets de l'hélium sur les échanges gazeux est discuté et son utilisation pendant l'insufflation lors de chirurgie des voies aériennes supérieures est passée en revue.*

Conclusion *L'ajout d'hélium améliore les échanges gazeux en ventilation spontanée pendant l'anesthésie générale lors de chirurgies des voies aériennes.*

Introduction

The therapeutic benefits and clinical applications of helium-oxygen gas mixtures were first reported over 70 years ago.^{1,2} Since then, clinical applications have included various pathologic conditions involving both the upper and lower airways.³ In the majority of clinical

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scenarios, a helium-oxygen gas mixture is delivered via a face mask or through a standard intensive care unit (ICU) ventilator.⁴ We report the administration of a helium-oxygen mixture during insufflation to facilitate gas exchange during spontaneous ventilation and general anesthesia, thus allowing for airway surgery without the need for an endotracheal tube (ETT).

Case report

The Institutional Review Board of the University of Missouri approved the review of this patient's medical records and the publication of this case report. The patient, an 8-year-old, 33 kg boy, had a history of subglottic stenosis and was status post tracheal reconstruction. The patient was delivered at 31 weeks gestation and required endotracheal intubation for 3–4 days during his neonatal course. Following discharge from the neonatal intensive care unit, he had no major medical issues other than a chronic complaint from his mother that he was a noisy breather. He developed progressive respiratory distress with stridor at 5 months and was admitted to the hospital for further evaluation. Direct laryngoscopy and bronchoscopy performed in the operating room revealed a 1.5 cm long segment of subglottic stenosis with a subglottic diameter of less than 2 mm. A tracheostomy was performed. Subsequently, a tracheal reconstruction was performed at another institution, and the patient's tracheostomy was eventually removed at 5 years of age. Due to multiple social issues, he was lost to follow-up until he presented with complaints of decreased exercise tolerance and a weak voice. Under general anesthesia with spontaneous ventilation, direct laryngoscopy revealed scarring of his supraglottic airway with the right arytenoid crossing the midline and interdigitating with the left arytenoid, thereby decreasing the cross sectional airway of the upper airway. The subglottic area was patent without narrowing. The patient's postoperative course was unremarkable, and a decision was made to undertake a supraglottoplasty at a later date.

For the subsequent procedure, the patient was held *nil per os* for 6 h, and he was premedicated with oral midazolam and transported to the operating room where routine American Society of Anesthesiologists (ASA) monitors were placed. Additionally, a transcutaneous (TC) CO₂ monitor (Radiometer America, Westlake, OH, USA) was placed on the patient's earlobe. Anesthesia was induced with sevoflurane in oxygen with the maintenance of spontaneous ventilation. Following induction of anesthesia, the patient's airway was suspended with the operating laryngoscope, and topical anesthesia was provided by the application of 1% lidocaine to the airway. Dexamethasone 0.25 mg/kg was administered

intravenously. Anesthesia was maintained by the insufflation of sevoflurane (inspired concentration 5–8%) in 40–50% oxygen with a flow of 6 l/min, administered through the side channel of the laryngoscope (the side channel exits at the distal tip of the laryngoscope). A Datex-Ohmeda anesthesia machine (Aestiva 5, GE Healthcare of North America, QC, Canada) with a built-in helium flow meter was used. The machine allows the administration of the helium-oxygen mixture using standard anesthesia machine flow meters and permits the delivery of this gas mixture to the vaporizers. During this time, the patient's respiratory rate varied from 26 to 30 breaths per minute. There was audible inspiratory stridor, as well as decreased gas exchange and suprasternal and intercostal retractions. Although the oxygen saturation remained from 94% to 96%, the TC-CO₂ increased from 46 to 68 mmHg. The oxygen flow and the helium, which was administered from a tank (80% helium-20% oxygen) attached to the anesthesia machine, were both started at 3 l/min. There was a decrease in the respiratory rate to 18–22 breaths per minute over the next 2–3 min, as well as increased air movement, decreased audible stridor, and resolution of the suprasternal and intercostal retractions. The helium flow was increased to provide an inspired oxygen concentration of 30%. The TC-CO₂ decreased to 50–53 mmHg, and the oxygen saturation remained at 94–96%. The surgical procedure, including the supraglottoplasty and release of the arytenoid scar bands, was performed using scissors, blunt dissection, and the CO₂ laser. During the 135 min surgical procedure, the patient was breathing spontaneously. He was observed overnight in the Pediatric ICU. The postoperative course was unremarkable, and the patient was discharged home on postoperative day one with resolution of the inspiratory stridor. Follow-up has demonstrated improved exercise tolerance with no further complaints.

Discussion

In the pediatric population, the laser is frequently used for the treatment of various acquired and congenital abnormalities of the upper airway. Various options exist for the maintenance of ventilation and oxygenation during such procedures, including the use of specialized laser-resistant ETT's, jet ventilation (supraglottic and subglottic), intermittent apnea, and insufflation. Given our clinical experience, we generally favour the use of insufflation with suspension laryngoscopy. This eliminates the presence of an ETT, thereby decreasing the risk of airway fires and providing an unobstructed surgical view of the airway. In these cases, the patient breathes a mixture of air and oxygen, which is used to deliver varying concentrations of sevoflurane through the side channel of the suspension

laryngoscope. This technique allows for the provision of general anesthesia with the maintenance of spontaneous ventilation without the need for an ETT during upper airway laser surgery.

In current clinical practice, a helium–oxygen combination is most commonly used to improve gas exchange in patients with upper airway obstruction of various etiologies, including infectious and post-intubation croup.^{5–7} The beneficial effects of helium have been realized in patients who have obstructive processes more distally along their tracheobronchial tree and who require mechanical ventilation for asthma and other respiratory disorders.^{8–10} Additionally, there are anecdotal reports of helium being used successfully in the operating room to treat respiratory compromise related to an anterior mediastinal mass, bronchospasm, and tracheal stenosis.^{11–13} During maintenance anesthesia in our patient, we noted the development of increasing upper airway obstruction and respiratory insufficiency manifested by increasing audible inspiratory stridor, decreased air movement, increased respiratory rate, suprasternal and intercostal retraction, and the development of hypercarbia with an increase of the TC-CO₂ from 46 to 68 mmHg. Following the introduction of a helium–oxygen mixture, there was a relatively rapid improvement in his respiratory status, with a decrease in all of the previously noted signs and symptoms.

There are several potential benefits of helium in patients with obstructive diseases at various points along the airway. Helium's primary effects are the result of its lower density and, therefore, decreased resistance during turbulent gas flow. Turbulent gas flow, as described by the Hagen-Poiseuille law, states that resistance is directly related to the density of the gas. Helium may also increase gas movement by converting turbulent flow to laminar flow by lowering the Reynolds number. The Reynolds number is the ratio of kinetic and viscous forces. It predicts whether flow will be laminar or turbulent (turbulent flow occurs with a Reynolds number ≥ 2000). Helium, because of its lower density and higher viscosity when substituted for nitrogen or oxygen, lowers the Reynolds number and may convert turbulent flow to laminar flow, thereby improving gas exchange. Helium also enhances the diffusion effect on the elimination of CO₂. Through a mixture of helium–oxygen, carbon dioxide diffuses four to five-fold faster than nitrogen–oxygen.^{14,15} Therefore, for the equivalent partial pressure of CO₂, a greater amount of CO₂ would be eliminated per unit of time. An advantage to using a helium–oxygen mixture during airway laser surgery is that it has higher heat conductivity than a nitrogen–oxygen mixture and, as a result, may decrease the risk of airway fire.¹⁶

There are logistic problems to consider when administering helium, regardless of the clinical scenario where it is

used. There have been reviews elsewhere regarding the administration of helium using a facemask during spontaneous ventilation and during mechanical ventilation through standard ICU ventilators.^{3,17,18} For our patient, helium was administered from a standard Datex-Ohmeda anesthesia machine (Aestiva-5), which has a separate flow meter, in addition to oxygen, air, and nitrous oxide. This machine allows the administration of helium from an E cylinder prior to the gas flowing through the vaporizers. Therefore, no specialized set-up or preparation was necessary, other than ensuring that the machine with helium was available in the operating room. Of importance is the fact that the helium flow meter does not participate in the ratio control that is present with the use of nitrous oxide and oxygen. Additionally, heliox is supplied in various concentrations or ratios of helium to oxygen. Therefore, when helium is in use, the delivery of a hypoxic mixture is possible. It is mandatory to use a separate in-line oxygen and anesthesia gas monitor as well as standard ASA monitors.

In summary, we present a unique case involving the intra-operative administration of helium via insufflation during spontaneous ventilation without an ETT for laser surgery of the upper airway. Although it is most commonly used in the ICU setting, there may be specific intra-operative applications of helium as demonstrated by our patient.¹⁸ We noted decreases of the signs and symptoms of upper airway obstruction and improved gas exchange with the administration of helium. We believe that the use of a helium–oxygen mixture facilitated the completion of the procedure without the need for controlled ventilation.

Conflicts of interest None declared.

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