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The Helium Protocol for Laryngotracheal Operations with CO₂ Laser: A Retrospective Review of 523 Cases

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Laser microsurgery of laryngotracheal lesions presents numerous anesthetic challenges. Airway management may be hampered because these lesions may obstruct the airway; also, because the airway constitutes the operative field, the anesthesiologist has limited access to the airway. Either deep anesthesia, skeletal muscle paralysis, or both with controlled ventilation are necessary because the surgical field must be immobile during resection to prevent the laser beam from falling on healthy tissue. Finally, there is the hazard of fire from ignition of flammable materials, such as polyvinyl chloride (PVC) tracheal tubes,¹⁻⁴ which risks airway burns.

A study at our institution showed that the risk of unwrapped PVC tracheal tube fire from CO₂ laser energy is much lower when the gas within the tube consists of helium/O₂ rather than N₂O/O₂ or nitrogen/O₂.⁵ Further, helium is less dense than nitrogen and, therefore, produces less airway turbulence, which improves air flow—a special advantage for patients with laryngotracheal lesions. In concentrations $\geq 60\%$, helium has delayed ignition of plain PVC tube segments for at least 20 s. Mean time to ignition was 45 s when unmarked areas of PVC tubes were exposed to a direct, continuous 10-W laser beam with a spot size of 0.8 mm, although parts of the tube containing barium sulfate ignited much sooner. Based on these data, we developed a clinical protocol, the "helium protocol," to prevent plain PVC tracheal tubes that are not wrapped from igniting during CO₂ laser operations (table 1). We have used this protocol in over 500 patients and now report our clinical results.

MATERIALS AND METHODS

The helium protocol was used for patients scheduled for laryngotracheal operations with the CO₂ laser, unless patients required that FI_{O₂} be greater than 0.4. Preoperative medications were prescribed by the anesthesiologist. Monitors used during operation consisted of electrocardiogram, precordial stethoscope, blood pressure cuff, peripheral nerve stimulator, temperature probe, pulse oximeter, capnograph, and O₂ analyzer. After 100% O₂ was breathed, anesthesia was induced either intravenously with thiopental, methohexital, or ketamine or by inhalation of halothane and N₂O. Tracheal intubation was facilitated by administration of a muscle relaxant: succinylcholine, atracurium, or vecuronium. Special-ordered PVC tracheal tubes that are unmarked and without a barium stripe (Mallinckrodt, Inc., Glen Falls, NJ) were used for endotracheal intubation. If there were a chronic tracheostomy stoma, the tracheostomy tube was replaced by a plain, unmarked PVC tracheal tube after anesthetic induction. Tracheal tube size and use of a tube cuff were decided by the anesthesiologist according to the patient's age and size and the nature of the airway lesion.

After tracheal intubation, mechanical ventilation was initiated; N₂O was discontinued and helium in a concentration of 60% was added to the anesthetic gas mixture. Standard laser precautions included application of saline-soaked gauze to the patient's eyes and protective goggles for operating room personnel. The anesthetic agent (halothane, enflurane, or isoflurane) that was used for maintenance was chosen according to the patient's condition. Narcotics and muscle relaxants were given as needed.

When the O₂ analyzer confirmed that FI_{O₂} was ≤ 0.4 , laser resection was begun with a power setting of 8 W and a spot size of 0.8 mm (Systems 450 CO₂ Laser, Coherent Medical Group, Inc., Palo Alto, CA). Tissue was vaporized by a series of brief (less than or equal to 10 s), repeated bursts of the laser beam; smoke, debris, and blood were evacuated by suction between each laser burst. When SaO₂ was $\geq 95\%$, the helium concentration was increased; if SaO₂ decreased to $<95\%$, the FI_{O₂} was increased to 0.4 again. If SaO₂ remained $<95\%$ with an

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TABLE 1. Helium Protocol for Laryngotracheal CO₂ Laser Operations

Protocol Consideration	Limitation
Gases	
Helium	≥60%
O ₂	FI _{O₂} ≤ 0.40
Inhalational anesthetic agents	Enflurane, halothane, or isoflurane, as indicated
N ₂ O	Cannot be used for anesthetic maintenance
Endotracheal tube	Plain, unmarked polyvinylchloride, unwrapped
CO ₂ laser	
Power density	≤10 W at 0.8-mm spot size (1,992 W/cm ²)
Exposure	Repeated bursts < 10 s of 0.5-s pulsed beam
Monitoring	Standard monitors, oxygen analyzer, pulse oximeter

FI_{O₂} of 0.4, laser resection was interrupted to increase FI_{O₂}, assess ventilation, and take any other necessary measures. If SaO₂ could not be kept at ≥95% with an FI_{O₂} of 0.4, or if the surgeon required greater than 10 W laser energy, the PVC tracheal tube was replaced with a metal tracheal tube.

RESULTS

Between January of 1982 and 1987, 148 patients underwent 523 laryngotracheal procedures according to the helium protocol for CO₂ laser resection of tissue, the number of procedures per year increasing from six in 1982 to 149 in 1986. Of the 523 procedures, the tracheas of 233 patients were intubated through tracheostomy stomas, and 290 patients had orotracheal intubation. The majority of the procedures were performed on patients younger than 15 yr of age (*n* = 360), all but 12 of whom suffered from juvenile papillomatosis or subglottic stenosis (table 2).

TABLE 2. Indications for Laryngotracheal Operations with CO₂ Laser

Diagnosis	Number of Cases (<i>n</i> = 523)
Juvenile papillomatosis	243
Subglottic stenosis	223
Benign vocal cord lesions	45
Neoplastic vocal cord lesions (laryngectomy revisions)	4
Tracheomalacia	2
Valecular cyst	2
Cystic hygroma	1
Esophageal web	1
Excision of teflon injectate	1
Trauma	1

Mean FI_{O₂} during the procedure was 0.36 ± 0.7, and remained less than 0.40 during laser firing. Oximetry data, which were available on 297 records, revealed a mean SaO₂ of 98 ± 1.9% (range, 80–100%). Episodes of SaO₂ < 90% (*n* = 13) were all brief and were a result of airway leaks or airway obstruction from tissue fragments or that occurred after tracheal extubation; in no case was the protocol abandoned due to arterial desaturation. Although 13 records indicated that the tracheal tube had been exposed to the beam and had to be changed due to leaking cuffs, there were no reports of tracheal tube fires or tracheal burns. There were no cases in which the surgeon requested that the power density be raised above the limits set in the protocol.

The protocol was not followed during one case when a tracheal tube cuff was punctured by the laser, which caused a significant gas leak and difficulty with ventilation. In an attempt to remedy the problem, the anesthesiologist filled the breathing bag by pushing the oxygen flush valve but did not notify the surgeon of this action, and laser resection continued. Shortly after the oxygen flush, a flash fire occurred on the tube, and laser exposure was stopped immediately. At the time of the fire, the oxygen analyzer indicated that FI_{O₂} was 0.70. Laryngoscopy at that time revealed minimal injury to the trachea. After tracheal extubation, the patient suffered no stridor or cough, and results of chest auscultation, oximetry, and chest roentgenogram were normal. One week after the procedure, fiberoptic laryngoscopy revealed minimal scarification at the site of the fire and, 3 months later, the patient remained asymptomatic.

DISCUSSION

Since the introduction of the carbon dioxide laser into laryngeal surgery, reports of tracheal tube fires have led clinicians to pursue various forms of prevention.⁴ This report is the first to describe a protocol for the use of helium in anesthetic/ventilatory gases. The greatest advantage of this clinical technique is that the tracheal tube is a polyvinylchloride tube, not unlike those used every day, the only difference being that the barium stripe and other markings have been eliminated because they increase the flammability of the tube.⁵ Such familiarity with method and tools is a safety factor that is especially important in patients in whom airway management is difficult due to laryngotracheal lesions.

Other advantages of the tracheal tube itself are that it is inexpensive and allows the use of conventional ventilation, capnography, and standard anesthetic agents and muscle relaxants. Metal jet injectors, which also have been used for carbon dioxide laser, may be ineffective when laryngotracheal lesions obstruct the airway

and may prevent the use of both inhaled anesthetics and non-invasive airway gas monitors. Polyvinylchloride tubes are soft and smooth and, therefore, less likely to traumatize friable lesions than are metal tubes⁶ or plastic tubes wrapped in metallic tape. Also, the surgeon can easily position the clear, pliable tube so that it does not impede visualization of the tissue being resected.

The index of flammability of polyvinylchloride is higher than that of either red rubber or silicone,⁷ and thus polyvinylchloride tubes are less likely to ignite than are other tubes common in clinical use. The polyvinylchloride tubes are available in all sizes and can be cuffed or noncuffed, which makes them useful in all but the smallest stenotic airways. While polyvinylchloride exposed to the laser energy used here does not ignite in room air, with oxygen enrichment of nitrogen at an $FI_{O_2} > 0.26$, the risk of fire is increased significantly.^{5,7} The major advantage of the helium protocol is that the risk of flammability with oxygen enrichment of the respiratory gases is decreased by using helium instead of nitrogen or nitrous oxide as the diluent gas.⁵

Helium is readily available, odorless, tasteless, chemically and biologically inert, and has no known toxic effects. With helium, an FI_{O_2} of 0.40 is safe and is usually high enough to maintain oxygen saturation in the normal range in the face of ventilation-to-perfusion mismatching, which can occur during positive pressure ventilation and inhalational anesthesia. Because of its low density, helium may improve ventilation by facilitating gas flow past airway obstruction.⁸

The helium technique does have limitations, the first of which is that FI_{O_2} must be less than 0.40. Among the cases we reviewed in which the helium protocol was adhered to, no fire occurred, even though, in at least 13 cases, the laser beam came in direct contact with the tracheal tube, as evidenced by cuff deflation (we collected 50 endotracheal tubes after their use in laryngotracheal laser operations, and found the incidence of contact to be much higher, on the order of 50%†). When the helium protocol was not followed, fire did occur; FI_{O_2} had been increased to 0.70.⁵ If the FI_{O_2} must be increased higher than 0.4, even temporarily, laser resection must be stopped until the oxygen concentration can be returned to between 21 and 40%. If a hole in the tracheal tube cuff results in an unacceptable leak, an appropriate response would be increasing gas flow while maintaining the same FI_{O_2} or replacing the tra-

cheal tube with one that has a competent cuff. Under no circumstance can oxygen flush be used to fill the breathing bag unless the surgeon has been notified and resection has been stopped.

Because oxygen concentration is critical in this protocol, an oxygen analyzer must be used to monitor the level of FI_{O_2} during laser resection. On current anesthesia machines, there is a device that ensures a minimal level of oxygen flow in proportion to total gas flow when nitrous oxide is used, but there is no such device for helium, so the analyzer should have alarm limits for both high and low levels of oxygen to ensure that FI_{O_2} is between 0.4 and 0.21. An oximeter should also be used to ensure that the concentration of oxygen being administered is clinically acceptable.

The helium protocol for laryngotracheal surgery requires that carbon dioxide laser output be limited to 10 W and that a beam spot size of 0.8 mm (power density less than 1,992 W/cm²) be used; also, the surgical technique must allow tissue to cool by delivering the beam in a series of repeated, brief bursts. The power density we specify is adequate to resect most tracheal pathologic tissue; in fact, power density of 1,000–2,000 W/cm² is considered advisable in laryngeal microsurgery to increase precision, promote hemostasis, and prevent burns to normal tissue adjacent to the pathologic tissue.**

A protocol to prevent fires during carbon dioxide laser resection of airway lesions requires that anesthetic gases contain helium in a concentration of 60% or more; that plain, unmarked polyvinylchloride tracheal tubes be employed; that carbon dioxide laser power density be limited to 1,992 W/cm²; and that the surgeon resect tissue by applying the laser beam in a series of short, repeated bursts. The protocol was used in a series of 523 cases. In 522 cases, the protocol was adhered to, and lesions were resected successfully without fire or complication related to the protocol. In one case, the technique was not followed (FI_{O_2} was increased to >0.4), and a flash fire occurred, fortunately without permanent damage.

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Comparison of the Analgesic Effects of EMLA (Eutectic Mixture of Local Anesthetics) to Intradermal Lidocaine Infiltration Prior to Venous Cannulation in Unpremedicated Children

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Fear of needles and the pain associated with venipuncture often makes iv cannulation prior to the induction of general anesthesia a traumatic experience for awake children. Many attempts have been made to obtain a suitable formulation of topically applied local anesthetics that can produce adequate skin anesthesia to allow painless venipuncture. Recently, a eutectic§ mixture of the local anesthetics (EMLA) lidocaine and prilocaine, which can penetrate the intact skin, has become available (table 1). This mixture has been shown to be effective in preventing pain associated with venipuncture in studies that compared EMLA to either a placebo or nothing at all.¹⁻⁴ This study compares prospectively the analgesic efficacy and acceptability of EMLA *versus* the current practice of intradermal infiltration with lidocaine (skin wheal) prior to venous cannulation in awake unpremedicated children.

MATERIALS AND METHODS

The study was approved by the Institutional Review Board, and informed consent was obtained in every case. Forty-two ASA Physical Status I unpremedicated children, ages 7-12 yr, scheduled for minor ambulatory

surgical procedures were studied. Younger children were not included, because we found from previous studies that they have difficulty using analogue pain scales. Children who had a history of allergy or hypersensitivity to the amide type of local anesthetics were excluded from the study. To avoid possible bias resulting from the selection of children who prefer or have already accepted an intravenous induction of anesthesia, participation in the study was offered as an alternative to undergoing phlebotomy for preoperative laboratory testing; a procedure that is required of all children in our institution.

Patients were randomly assigned to one of two groups. Children in group I had 2.5 g of 5% EMLA cream applied over the anticipated venipuncture site on the dorsum of the nondominant hand. The cream was covered with an occlusive dressing for 60 min, the recommended optimal application time for EMLA to be fully effective.² After the 60 min, the occlusive dressing was removed and the skin was wiped dry and inspected for local reaction. The skin was then cleaned with 70% isopropyl alcohol and allowed to dry prior to iv cannulation. Children in group II had the corresponding skin area infiltrated with 0.2 ml of 1% lidocaine using a 30-gauge needle. All venipunctures were performed by the same investigator. The patient's response was assessed first during the performance of a skin "nick" using the bevel of a 19-gauge needle, and again during the actual iv cannulation, which was accomplished by using a 20-gauge catheter in all cases. Blood for routine laboratory testing was withdrawn from the iv cannula. The cannula was then flushed with a dilute heparin solution, taped and secured on an armboard for use during induction of anesthesia.

The patient's response to venipuncture was scored by the anesthesiologist performing the venipuncture, an

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§ A eutectic "mixture" is the liquid formed from specific solid constituents at the lowest possible temperature.