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Anesthesia for Neodymium–YAG (Nd–YAG) Laser Resection of Major Airway Obstructing Tumors

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The development of technology to permit passage of laser energy through fiberoptic filaments allows ablation of previously nonoperable airway obstructions and improvement in respiratory function.[1–5] Until development of neodymium–yttrium-aluminum-garnet (Nd–YAG) laser, resection of these airway lesions was done primarily by carbon dioxide laser. Use of the carbon dioxide laser is restricted by a wavelength (10,600 nm) that is too long to permit passage of significant energy through a flexible bronchoscope.[6] Thus, lesions not visualized through a rigid bronchoscope are inaccessible. The argon laser has a shorter wavelength (514 nm) that will pass through a fiberoptic filament. However, argon energy is absorbed by hemoglobin, thus limiting tissue penetration. Nd–YAG laser (wavelength 1,064 nm) is conducted readily through fiberoptics, is poorly absorbed by hemoglobin, and has good tissue penetration.[4] These qualities make it suitable

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for resection of airway lesions beyond the direct range of a rigid bronchoscope.

Several potential anesthetic problems may exist during laser resection in patients with such lesions. These include 1) ventilation and oxygenation through a compromised and shared airway; 2) possible combustion of inhaled anesthetics;[7] 3) prolonged procedures requiring paralysis and anesthesia; and 4) resection of tumors adjacent to vascular tissues. To study these problems, we reviewed the perioperative course of a group of adult patients undergoing Nd–YAG laser photovaporization at our institution.

Methods

From March 1982 to February 1983, 22 adult patients with life-threatening, nonoperable obstructions of a major bronchus with or without involvement of the carina underwent treatments with the Nd–YAG laser. These obstructions resulted from squamous cell carcinoma (9), cylindroma (5), metastatic adenocarcinoma (3), primary adenocarinoma (2); and carcinoid tumor, Hodgkin's lymphoma, and a benign obstructing stricture (1 each). The medical, anesthetic, and respiratory records for each of these patients were reviewed following laser therapy to ascertain specifics of their anesthetic, surgical, and postoperative management and any associated morbidity and mortality.

Anesthesia was induced with thiopental iv and intubation of the trachea performed after paralysis induced by succinylcholine iv. Diazepam, fentanyl, and/or enflurane was used for maintenance of anesthesia. A succinylcholine infusion or a nondepolarizing muscle relaxant was given to induce paralysis. Ventilation was controlled with an $Fi_{O_2} < 0.5$ in N_2 during actual resection. Analysis of arterial blood gases and ear and/or mixed venous oximetry were used to monitor oxygenation and ventilation. If oximetry indicated rapid desaturation during prolonged periods of resection, laser therapy was interrupted and ventilation with high concentrations of oxygen resumed until adequate oxygen saturation was obtained.

For resection, an Olympus BF-1TR flexible bronchoscope of 6 mm diameter with a 2.6 mm working channel was introduced into the airway through the diaphragm of a ventilating endotracheal attachment. The fiber of the laser system (Molectron Model 8000) was passed through the working channel. This fiber consists of a 400-μm monofilament quartz fiber coated in Teflon® and surrounded by a 2.5-mm diameter polyethylene sheath. Through it, pulsed power in the near infrared region (1,064 nm) was conducted at levels of 50–90 watts for durations of 0.5–2 seconds. A xenon pilot beam conducted through the fiber projected a bright red spot to the same position and in the same size as the invisible laser beam. This pilot light permitted accurate aiming with a fiber-to-target beam distance of only 5–10 mm. At this distance, the laser beam divergence was less than 10 degrees, with an area of photovaporization 1–2 mm in diameter. A continuous 3.0 l/min flow of air through the coaxial sheath of the fiber kept the fiber tip clean and maintained a clear visual field.

TABLE 1. Incidence of Various Factors in Anesthesia and Surgery

1. Ventilation and oxygenation:
   Hypercarbia (30/32): Pa_{CO_2} range 45–60 mmHg
   Changes in oxygenation were variable
   Subjective improvement in dyspnea (29/32)
2. Combustion: none
3. Prolonged procedures: postoperative controlled ventilation (5/32)
4. Intraoperative deaths from uncontrollable hemorrhage (2/32)

Results

The 22 patients underwent a total of 32 Nd–YAG laser treatments. Procedure times ranged from 45 to 240 minutes with total energy doses of 180 to 32,321 joules. There were 15 males and 7 females ranging in age from 28 to 78 years. Anesthetic maintenance included the use of iv drugs alone in 20 cases, enflurane alone in four, and a combination of these in eight.

Hypoventilation was a problem in 30 of the 32 procedures conducted with controlled ventilation during resection; arterial carbon dioxide tensions (Pa_{CO_2}) ranged from 45 to 60 mmHg (table 1). Changes in oxygenation were variable and dependent on the establishment of an airway through the obstructed and involved lung. Dyspnea, present in all 32 patients prior to the procedures, improved immediately following resection in 29 of them. There were no combustion mishaps. Prolonged procedures using iv anesthetics resulted in postoperative somnolence and respiratory depression requiring controlled ventilation in five instances. This did not occur in any patient anesthetized with enflurane. Two patients required rapid reintubation and support within 24 h postoperatively when edema obstructed a major airway. There were two intraoperative deaths (9.1%), both from uncontrollable hemorrhage during resection. These occurred during resection through lesions that totally obstructed a major airway.

Discussion

The high mortality rate of 9.1% resulted from resection through totally obstructed airways. Margins of such lesions are poorly delineated, and laser energy may cut through airway walls into adjacent vessels. The resulting hemorrhage was massive and uncontrollable. Conventional management of pulmonary hemorrhage is not feasible.

Double lumen endotracheal tubes do not accommodate the 6-mm Nd–YAG fiberendoscope and bleeding is usually too brisk to control with occlusion catheters. This problem may be resolved with intravenous staining of the tumor tissue with methylene blue for margin identification and with more experience resecting such lesions.

Significant airway edema may occur after laser resection and reocclude a major airway. This occurred following prolonged extensive resections. If the bronchoscopist can ablate a small obstruction readily and easily, it is not necessary to watch these patients for long periods postoperatively. However, any patient who has had either a prolonged resection or removal of a large obstruction should be monitored carefully for 24 h following surgery.

Respiratory depression often follows prolonged procedures in which only iv anesthetics are used to provide general anesthesia. Since changing to inhaled anesthetics, we have not encountered this problem. To reduce support of possible combustion, we avoid nitrous oxide and keep the Fi_{O_2} below 0.5 during Nd–YAG laser resection as recommended by Vourc'h.[1] Ignition of flammable endotracheal tubes during Nd–YAG resection is not a high risk because the laser beam is delivered distal to the end of the tube.

Controlled ventilation usually results in moderate hypercarbia (Pa_{CO_2} 45–60 mmHg) during these procedures. This problem is secondary to partial occlusion of the endotracheal tube by the bronchoscope in addition to the preexisting pathologic occlusion of a major lung field. Therefore, a large endotracheal tube is placed to provide maximum remaining luminal area for ventilation. Jet ventilation via a small metal endotracheal tube can be used to deliver oxygen and air for this procedure but not volatile anesthetics.[1] We found the use of volatile anesthetics superior to iv anesthetics for prolonged resections. For this reason, we have not used jet ventilation but instead choose conventional controlled ventilation.

Based on our experience, general anesthesia using inhaled anesthetics with an $Fi_{O_2} < 0.5$ in N_2 during Nd–YAG laser resection of otherwise nonoperable and life-threatening major airway lesions is safe and not associated with either prolonged respiratory depression or risk of combustion. Mortality from massive hemorrhage is high. Because significant airway edema and occlusion may occur postoperatively and require immediate ventilatory support, we recommend that these patients be observed carefully for 24 h after surgery.

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Acute Sinus Arrhythmia during Surgery in the Fourth Ventricle: An Indicator of Brain-stem Irritation

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Surgical procedures on or near the brain stem may involve risk of injury to lower cranial nerve nuclei and respiratory centers. Because of the proximity of these areas to the centers that govern cardiovascular function, the occurrence of abrupt cardiovascular changes has been used as an indicator of impending injury. Hypertension and tachycardia, bradycardia and hypotension, ventricular dysrrhythmia, and, occasionally, bradycardia and hypertension are recognized responses to brainstem and/or cranial nerve irritation. Their occurrence should prompt an immediate warning to the surgeon.

We have observed an additional cardiovascular sign that may indicate brain stem injury. Two patients undergoing resection of posterior fossa tumors abruptly developed marked sinus arrhythmia during dissection on the floor of the fourth ventricle. This report details those

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