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ORIGINAL ARTICLE

Anesthesia for Laser Surgery of the Airway

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ABSTRACT

Anesthesia for laser surgery carries a number of particular challenges and pitfalls. The airway is not only shared with the surgeon but also being operated upon. Personnel working inside the operating room must also be very aware of the benefits and dangers of medical lasers, and safety precautions must be taken to ensure their proper use. The anesthetist must have the knowledge and expertise to anesthetize a patient with a potentially compromised airway. This article deals with the anesthetic management of a patient presenting for laser surgery of the airway.

Keywords: Airway, Anesthesia options for laser surgeries, Fires, Laryngeal cancer, Laser.

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INTRODUCTION

Laser surgery offers several advantages to the surgeon and patient, i.e., microscopic precision, a bloodless operative field, reduction of tissue reaction, preservation of normal tissue, and complete sterility.[1] It is therefore no wonder that more and more surgeons prefer to operate lesions in the upper airway using lasers. However, anesthetists have to face the challenges posed by the obstructed upper airway while taking precautions to avoid dangers caused by the laser beam. Some of the most common surgeries of the airway performed using lasers are laryngeal cancers or papilloma excision, vocal cord nodule/cyst removal, postcorrosive or traumatic tracheal stenosis, obstructing tumor, vocal cord dysfunction,[2] etc.

LASERS

The laser beam[3-5] is a source of energy that can be focused on an extremely high intensity and is capable of vaporizing tissues or photocoagulation replacing the surgeon's scalpel to the microscopic level. However, lasers can be dangerous as it can be invisible and be misdirected or can ignite some anesthetic gases or endotracheal tubes and damage normal tissues. In upper surgery of the airway, the CO_2 laser or the neodymium-doped yttrium aluminum garnet (Nd:YAG) laser is commonly used. The CO_2 laser wavelength is 10.6 µm and is strongly absorbed within 200 µm of any tissue traversed. Hence, it is extensively used for removal of laryngeal lesions, skin lesions, etc., Nd:YAG lasers are preferentially absorbed by pigmented tissues. Carbon dioxide laser in otolaryngological practice is used in tympanoplasty, myringotomy, stapedectomy, excision of laryngeal and tracheal papillomas, vocal cord polyps, nodules, keratoses, and localized cord carcinomas, choanal atresia, subglottic stenosis, and soft tissue lesions in the neck (lymphangioma, neurofibroma, subglottic hemangioma). Neodymium-doped yttrium aluminum garnet laser is used for tracheobronchial lesions via a fiberoptic bronchoscope.[6]

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Hazards of Laser Surgery

Hazards to Operating Room Personnel and Operating Team

The laser being a high-intensity beam should be used carefully. Specular reflection, as from a mirror surface, changes the direction of the beam without changing the focal properties and can thus direct the full power of the beam in an unintended direction. Matting the surfaces will avoid the deflection and reduces the energy density. The eye is the most susceptible tissue to injury by laser radiation. Carbon dioxide can affect the cornea, and Nd:YAG laser can affect the retina. Personnel inside the operating room should wear safety glasses, which should fit well around forehead and have side shields to protect the lateral part of the eye. Assuming that the laser beam is not reflected and also for the fact that the energy density decreases beyond the focal point, skin shield is not necessary. A proper conspicuous sign should be placed in the outside of the door leading to the operating room for safety to people entering the room.[7,8]

Hazard to the Patient

Hazards to the patient could be due to fires or destruction of normal tissue.

Fire Hazards: Fire occurs when the laser beam strikes a combustible object, such as an endotracheal tube. The chance of a fire hazard occurring during laser surgery

of the airway depends on the material on which the laser beam is striking, the gas surrounding it, and the focus of the laser beam. The regular rubber and plastic endotracheal tubes can be easily ignited by a well-focused laser beam in the presence of 100% oxygen. Nitrous oxide supports combustion. Hence, it is advisable to use air with oxygen to eliminate fire hazard. Halogenated anesthetics like isoflurane, sevoflurane, etc. do not support combustion and are not flammable. Since both rubber and plastic tubes are equally dangerous to be used in isolation, it can be used by protecting the tubes with an aluminum foil to minimize risk. Indirect burning of endotracheal tube due to ignition of pieces of tissue inside the tube can occur and is called arcing. There are many methods currently available to avoid the fire risk.

- No tube in the airway
- Protecting the outside of the tube by wrapping it with various materials
- Use a noncombustible tube

Damage to Normal tissue: Destruction of normal tissue occurs when the laser beam is misdirected or reflected into unprotected tissues. This can cause complication to the patient or to personnel inside the operating room. Good technique by the surgeon and an immobile target which is the responsibility of the anesthesiologist will minimize tissue injury. The tissues adjacent in the operative field can be protected by water moist gauze pads, sponges, or swabs. The patient's eyes should be covered by moist eye pads after taping them. Routine surgical drapes covering the entire arm usually protect the skin from the laser beam.

Anesthesia for Laser Surgery of the Airway

Anesthesia for laser surgery of the airway poses unique problems due to sharing of the airway as well as the use of laser.[9-12]

Preoperative Assessment

A meticulous preoperative history and physical examination[13] should determine the degree of existing airway obstruction, ease of breathing which may reflect adequacy of ventilation, presence of hoarseness, stridor, and hemoptysis. Patients usually present with cough, hoarseness, odynophagia, dysphagia, pain due to cartilage invasion, etc. Positional exacerbation of airway symptoms is usually due to pedunculated tumors of the glottis. Sudden breathlessness with panic in the middle of the night is of critical obstruction. The anesthesiologists should plan the anesthesia technique based on the potential threat to the airway and be prepared with rescue measures including tracheostomy in the presence of an airway emergency. The patients should undergo indirect laryngoscopy by the surgeon. Computed tomography images may be constructed in three-dimensional format to provide accurate anatomical deviations. Cross-sectional imaging techniques also provide information on intrinsic obstruction of the airway. Based on the findings, the anesthesiologists and surgeon should discuss the plan preoperatively.

The most important factor would be to predict the ease of ventilation with a face mask and ease of intubation with direct laryngoscopy. If either is in doubt, the patient's airway should be secured prior to induction by using alternative technique, such as use of fiberoptic bronchoscope or tracheostomy under local anesthesia. Comorbidities if any should be optimized in the preoperative period. Dyspnea from chronic airway obstruction must be distinguished from dyspnea from airway disease. Hence patients should undergo tests like pulmonary function tests including flow-volume loops, arterial blood gas analysis, etc.

Premedication

Premedication[14] with an opiate and a sedative along with anticholinergics are safe in patients without a compromised airway. This can be achieved by giving intravenous injections of Inj. glycopyrrolate 0.004 mg/kg, Inj. fentanyl 1 µg/kg, Inj. midazolam 0.02 mg/kg, and Inj. ondansetron 0.08 mg/kg. Inj. dexmeditomidine 1 µg/kg has been found to be a very useful premedicant in predicted mild or suspected compromised airways as it produces good sedation without respiratory depression. In a compromised airway, no opiate or sedative premedication is given.

Anesthesia Goals

Anesthesia goals include profound muscle paralysis to provide masseter muscle relaxation for introduction of scope, immobile surgical field, adequate oxygenation, ventilation, and cardiovascular stability during period of surgical stimulation. Profound relaxation is required until the end of surgery and rapid recovery is essential.[13,14]

Monitoring

A multipara monitor to measure heart rate, rhythm, saturation, end-tidal CO_2, temperature, and respiration is mandatory.[15]

Induction of Anesthesia

In the absence of airway obstruction, standard intravenous/inhalation induction technique can be used.[12-15] In a patient with compromised airway, an experienced anesthetist and surgeon should plan the technique to secure the airway based on result of previous nasoendoscopy. If Plan A fails, plan B/C etc. should be in place.

To this effect, various airway gadgets should be kept ready. This includes a variety of laryngoscopes, airways, bougies, endotracheal tubes, bronchoscopes (fiberoptic bronchoscope/direct or video endoscope), videolaryngoscopes, cricothyrotomy set, surgical minitracheostomy set, as well as a standard tracheostomy set. A jet ventilator should be attached in case of sudden loss of airway. An experienced ear, nose, and throat (ENT) surgeon capable of performing a quick tracheostomy should be in attendance. An awake intubation using fiberoptic bronchoscope is best in obstructed patients. Blind awake is best avoided as it may convert a partial obstruction to a total obstruction due to trauma and bleeding. In children and uncooperative patients, inhalation induction using sevoflurane in oxygen with spontaneous ventilation is the technique of choice. Ketamine is avoided as it increases airway reflexes causing laryngospasm and further obstruction.

Anesthesia Techniques

As mentioned earlier, safety from fire hazard is possible by using one of the following techniques: No tube, use of noncombustible tube, or protecting the external surface from a conventional tube.

No Tube with Spontaneous/ Controlled Ventilation

Larynx is either anesthetized with blocks or topical anesthesia and the patient induced with standard drugs like thiopentone or propofol along with fentanyl and midazolam.[16-20] Anesthesia is maintained using a nitrous oxide–oxygen mixture with a noninflammable agent like isoflurane/sevoflurane[17-19] via nasal catheters. The other method is to give relaxant while maintaining depth with propofol while jet ventilating the patient.[19-22] However, one has to be aware of the complications of jet ventilation: Pneumothorax, pneumomediastinum, inflation of stomach, aspiration of resected material, dehydration of mucosal surface, etc. In this method, the surgeon and anesthetist alternately share the airway. The advantage of this method is that the surgeon gets to work in the larynx without any hindrance of the presence of endotracheal tube. The disadvantage of the spontaneous ventilation technique is that the patient does not consistently maintain an adequate depth of anesthesia. Too light a plane may cause laryngospasm and too deep a plane may cause hypoventilation or apnea with potential for cardiac arrhythmias. If a relaxant is not used, the vocal cord does not remain mobile, causing damage to normal tissue. Also, anesthetic gases are wasted through the open mouth causing pollution to the operating room as scavenging is difficult.

Protecting External Surface of Conventional Tube

In this technique, a red rubber or a vinyl plastic tube cuffed tube which is 1 or 2 sizes smaller than the right size for the patient is chosen.[23] Uncuffed tube may be used in children if not available. The cuff is inflated with saline and not air. The tubes are wrapped well in a spiral manner with an aluminum or copper adhesive tape. The covering of the tube should start near the cuff and ends in the uvula. The covering is done in such a way that every spiral covers two-third of the previous spiral so that there is no chance of having an uncovered area in the tube around the surgical field. Few potential complications are possible with the use of foils. The foil can loosen and break off causing aspiration of the foil. Kinking of the tube is also possible. A recommendation by Patil et al is to wrap the tube with moistened muslin. The water or saline in the muslin prevents ignition and dissipation of laser energy. The disadvantage of this technique is that the muslin needs to be moistened frequently by an epidural catheter or by the surgeon so that the dry muslin does not catch fire. The FiO_2 should be limited to the lowest concentration necessary to maintain acceptable arterial O_2 saturation. The balance of the fresh gas flow should be nitrogen and/or helium potent; nonflammable inhalation agents may be added as clinically indicated. Nitrous oxide should not be used. Muscle relaxant should be used and the patient should not be allowed to buck as this may misdirect the laser beam. The laser output should be limited to the lowest clinically acceptable power density and pulse duration. Conventional oil-based ointment used to lubricate the tube should be avoided as it is inflammable. A water-soluble local anesthetic cream is safe to use.

Laser Fire

Should a fire occur,[24] disconnect the tube from the gas source immediately as most tubes do not burn in air. The lung as well as the trachea may be injured extensively due to smoke inhalation or direct thermal burns. Chest X-ray and bronchoscopy are performed to assess the extent of the injury. Steroids, humidification of inhaled gases, tracheostomy, and postoperative ventilation for a prolonged period may be necessary. Tracheal stenosis can occur as a late complication. The laser beam can rupture the cuff creating a leak with inadequate ventilation. Hence, it is mandatory to place saline-soaked gauze pieces between the vocal cords and the cuff.

Noncombustible Tube

There are many tubes which are partly noncombustible for use in laser surgery of the airway.[25-30]

- *Bivona foam cuff tube*: This has an aluminum and silicone rubber spiral with a silicone covering and a

self-inflating foam sponge cuff. This tube has a nonflammable inner surface. The cuff tends to maintain a seal despite penetration by the laser. *Disadvantages*: Flammable external surface and cuff. It may be difficult and time-consuming to deflate the cuff, if the cuff or inflation tube is damaged.

- *Laser flex*: This has an airtight stainless steel corrugated spiral with a Polyvinylchloride Murphy eye tip and double cuffs. An uncuffed version is available for pediatric use. This item is intended for use with CO_2 or potassium titanyl phosphate (KTP) lasers. *Advantages*: Metal components are noninflammable. The tube maintains its shape during intubation and is kink-resistant. The proximal cuff serves as a shield for the distal tracheal cuff. *Disadvantages*: The metal may reflect the laser onto nontargeted tissues and cause damage; the matte finish and convexity of this product reduce this potential. The cuffed model contains materials which are flammable and requires that the cuff be inflated with saline to decrease the risk of ignition. Metal tubes are thick-walled. The double cuff takes more time to inflate and deflate than a single cuff. Also, the metal may transfer heat to adjacent tissue and other materials.
- *Laser-Shield*: This is a silicone rubber tube covered with an aluminum-filled silicone layer. *Advantages*: General characteristics are similar to unwrapped conventional tracheal tubes. *Disadvantages*: It can be ignited by lasers in the presence of room air and is difficult to extinguish once ignited.
- *Xomed Laser-Shield Tube*: This item has replaced the original laser shield. This is a silicone rubber tube wrapped with aluminum and wrapped over with Teflon (no adhesive is used in this process). Methylene blue is contained in the pilot balloon. *Advantages*: The wrapping may prevent the laser beam from igniting the tube yet still allow use of a pliable tracheal tube. The Teflon coating is smoother and less traumatic than most manually wrapped tubes. The methylene blue in the pilot balloon will mix with normal saline and provide a marker of cuff perforation. An additional advantage of this product over tubes wrapped by the practitioner is that it is preassembled. *Disadvantages*: If the tape is dislodged, it can occlude the airway. Tubes cannot be wrapped on or below the cuff, so this area remains exposed and vulnerable to laser energy. These tubes confer no advantage when the site of operation is distal to the tube and/or the laser beam is delivered through the lumen of the tube. Combustion and pyrolysis of Teflon yields toxic fluorinated by-products.
- *Laser-Shield Tube*: This is silicone rubber tube uniformly impregnated with ceramic particles. *Advantages:* General characteristics are similar to unwrapped conventional tracheal tubes. The cuff is thicker on the machine side to provide somewhat better resistance to laser puncture than most cuffs. *Disadvantages:* It can be ignited or punctured by laser energy.
- *Metal Tracheal Tubes*: These are flexible, nonairtight, interlocked metal spiral tube[31] with a standard 15-mm tracheal tube adapter attached. These tubes are reusable. *Advantages*: Under these conditions, metal is nonflammable. *Disadvantages*: These metal tubes are technically difficult to place in the airway and have joints through which airway gas can leak. The metal may reflect the laser energy to nontargeted tissues and result in damage. The corrugated outer surface of metal tubes may injure mucosa. Metal tubes are thick walled and may transfer heat to adjacent tissues and other material. Nortan tube is a metal tube with a large external diameter. Porges Milhaud tube is under evaluation.

Jet Ventilation through a tube: The Nortan and Porch tubes can be attached to Venturi apparatus. The Porch tube can be used only with jet ventilation. The internal diameter is small (3 mm) offering too much resistance and hence cannot be used for spontaneous/controlled ventilation. Exhalation of gases occurs around the tube and hence adequate space should be there around the tube.

Anesthesia in patients with tracheostomy: Metal tracheostomy tubes without fenestrations are safe to use. Resection of tracheal papillomas in children with tracheostomy is difficult. Though induction is easy, the surgeon and anesthetists use the airway alternatively and this could be a problem. Alternatively, a metal tube can be introduced through the vocal cords and ventilation can be achieved using a Venturi with expiration from the tracheostomy stoma. By this method surgical access is uninterrupted and ventilation is adequate. In smaller children where Venturi cannot be used spontaneous ventilation through the metal tube under deep anesthesia is given. Cardiac dysarrhythmias, hypoventilation are the disadvantages.

Postoperative Considerations: The patient is extubated in the operating room in the majority of the cases. The endotracheal tube should be inspected for absence of foil or any adhesive wrapping in the tube. If the ape is missing, bronchoscopy should be done to remove the tape. Postoperative edema can occur and is manifested as stridor and retractions. Humidified oxygen is given. Spraying of cords reduces postoperative laryngospasm. A chest X-ray should be done in those patients in whom Venturi was used to rule out pneumothorax.

SUMMARY

Anesthesia for laser surgery of the airway poses unique problems for the anesthesiologists. The anesthesiologists and the surgeon should have good communication preoperatively and throughout the procedure. The anesthesiologists should have the plan for anesthesia ready and also be prepared if a change in plan is needed at the time of induction. The anesthesiologists should understand the basic principles and application of laser. In the event of any unexpected complication like a laser fire, the anesthesiologists should be able to quickly identify and interrupt the flow of oxygen/nitrous oxide as against the reflexes of an anesthesiologist to give 100% oxygen in times of any catastrophe.

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