Lasers and anesthesia

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The authors report on the results they obtained utilizing elective microsurgical therapy by carbon dioxide laser on a variety of benign and malignant lesions of the larynx and tracheobronchial tree, including a great number of recurrent papillomas, under general endotracheal anesthesia. Their study focuses on 250 consecutive pediatric and adult patients who entered University Hospital in Boston, Massachusetts, during a 42-month period from December 1, 1971, to June 1, 1975.

The laser has become accepted as a viable clinical method with a variety of therapeutic and surgical applications. It has been used extensively in ophthalmology for therapy of retinal disorders, in otolaryngology for treatment of tumors of the larynx and trachea, in dermatology for treatment of benign lesions of the skin, in surgery for hemostasis, and in gynecology for therapy of erosions of the cervix, and it is becoming more and more useful in other fields of medicine.

The practicality of using a carbon dioxide laser in laryngeal surgery has been established. At University Hospital in Boston and other medical centers, the carbon dioxide laser has been used to remove a variety of benign and malignant lesions of the larynx and tracheobronchial tree under general endotracheal anesthesia.

The laser light

Each atom has a nucleus, and around this circulate a number of electrons. The distance between an electron and the nucleus can be changed, but only if the electron jumps to another pre-determined level. The electron has the tendency to return to its lowest energy level (ground state).

If energy (light, heat, electricity) strikes an atom, and if this energy is absorbed by that atom, the electron will jump to a higher level. This atom is in the excited state. As the electron returns spontaneously to its normal energy level, it releases energy in the form of a photon, which is the smallest quantity of light.

When a photon bombards another atom that is in the excited state, then that atom’s electron will fall back to its ground state, releasing another photon. This photon has the same frequency as the incoming photon, so it is “in step” with it and moving in the same direction. This is called stimulated emission. If there are other atoms in the excited state, then these photons will continue to multiply in a chain reaction.

For the production of laser light, a ruby crystal is used, in which a great number of atoms are in what is called the ground state. If energy strikes the ruby crystal in the form of light from a xenon flash tube, a great portion of the atoms will go into the excited state. A few atoms will then release photons moving in random directions, but a few
other photons will travel along the axis of the crystal and stimulate yet other atoms to release photons.

If two special parallel, reflective mirrors are located at each end of the ruby crystal, released photons will move back and forth between these two mirrors, stimulating other atoms to emit photons with the same phase, frequency, and direction. If one of the mirrors is partially transparent, part of this radiant energy will escape through it in the form of a powerful beam of parallel, monochromatic, and coherent light. This is known as *Light Amplification by Stimulated Emission of Radiation* (LASER). This beam then can be focused, aimed, calibrated, and controlled as a very useful surgical instrument.

Two types of lasers are in use: (1) the pulsed (ruby) laser, and (2) the continuous wave (argon and carbon dioxide) laser.

**Lasers in medicine**

A variety of materials can stimulate laser emissions. The most common materials used in medicine for solid lasers are: (1) ruby rods, (2) neodymium, and (3) neodymium yttrium aluminum garnet (NdYAG). In the gas lasers, the materials used are: (1) helium neon, (2) argon, and (3) carbon dioxide.

**The carbon dioxide laser**

The continuous carbon dioxide laser was discovered in 1964. Shortly thereafter, the research group of the American Optical Company developed methods of producing, transmitting, and focusing such energy. It was found that this form of nonionizing, invisible, electromagnetic radiation had potential as a surgical instrument. The development of the basic carbon dioxide surgical laser, with handpieces containing lenses of varying focal lengths, was followed by the development of the laser endoscope and the stereomicroscope laser attachment.

The wavelength of the laser beam delivered by this instrument is in the infrared range (10.6 microns), so that the destruction capacity of the beam is a thermal effect. This energy is absorbed by all biological tissues, irrespective of pigmentation and the amount of tissue. Destruction is, in part, proportional to the tissue's water content. This form of nonionizing radiation can be used to vaporize predetermined volumes of tissue in a precisely controlled fashion by using the appropriate amount of energy.

The instrument used with our patients is contained in a standard electronic relay rack. The laser beam is focused on the target by an articulated arm that is attached to the surgical microscope or bronchoscope. A rheostat controls the power of the beam, and a foot-switch-controlled shutter allows the beam to impact on the target area for an appropriate period. In the operating room, a slow flow of tap water is required to cool the laser tube. The laser tube draws 15 amp of electrical power from the ordinary 110-volt outlet.

The laser beam can be focused to a fine point with the aid of a lens. This concentrated energy can be used to vaporize soft tissue in a linear fashion. The incision is clean and straight. There is minimal bleeding, because the small vessels are cauterized simultaneously. There is no visible postoperative edema, and the wounds heal with very little postoperative scarring.

**Management of general endotracheal anesthesia**

*In children.* Almost all the children in this study arrived at University Hospital, Boston, with histories of multiple previous exposures to general anesthetic drugs. They were fearful and apprehensive.

In the basic technique, nitrous oxide, oxygen, and increasing concentrations of enflurane or halothane are flowed over the patient's nose and mouth; and a few minutes later, the mask is firmly applied to the patient's face.

When the child is asleep, a stetho-
scope is placed on the precordial area to monitor the heart and ventilation, and the electrodes of the electrocardioscope are attached to the patient’s chest to observe the electrical activity of the heart. An intravenous (IV) infusion is started in the upper or lower extremities via a 20-gauge plastic catheter, with dextrose 5 per cent in water 500 ml and running through a microdrip. To this, succinylcholine 0.2 per cent (2 mg/ml) in dextrose 5 per cent in water 500 ml with a microdrip is attached. In addition, blood pressure, body temperature, and the degree of the effects of succinylcholine with a nerve stimulator are monitored and recorded.

Oral intubation with a Rusch uncuffed, red-rubber tube, 3 mm in internal diameter, wrapped with aluminum tape, is facilitated with nitrous oxide, oxygen, enflurane or halothane, and a continuous administration of succinylcholine. Maintenance of anesthesia is accomplished with nitrous oxide (3 L/min), oxygen (2 L/min), enflurane 2.3 per cent or halothane 1.2 per cent, succinylcholine 0.2 per cent in a continuous slow drip, and manual control of respiration by the semiclosed circle absorption technique.

An ophthalmic ointment is applied to both eyes, and the eyelids are kept closed with wet eye pads. Methylprednisolone 20 mg may be injected IV during the induction of anesthesia, and again, in the same amount a half-hour later. This is done in order to prevent swelling and edema from mechanical irritation by laryngoscopes and other instruments.

Exposure of the larynx is accomplished with a pediatric laryngoscope placed on the suspension apparatus, followed by the positioning of the operating microscope with the laser attachment. The microscope is fitted with a 400 mm front lens, which makes possible an excellent binocular view of the vocal cords. At the end of the procedure, the vocal cords are sprayed with lidocaine 4 per cent. In the postanesthesia recovery room, the patient is placed in an oxygen tent. There is no postoperative pain other than that associated with the use of the instruments. The child is discharged the next day.

In adults, tubocurarine 3 mg or pancuronium 1 mg IV is injected, and induction of anesthesia is done by IV infusion of thiopental 2.5 per cent, 250-300 mg. Succinylcholine, 80-100 mg IV, is administered, and exposure of the larynx is performed via a laryngoscope. A firm, cuffed, red-rubber Rusch endotracheal tube, 5-5.5 mm in internal diameter, is inserted into the trachea.

Anesthesia is maintained with N₂O-O₂ (3:2 L/min), enflurane 2-3 per cent, succinylcholine 0.2 per cent in continuous slow drip, and manually controlled ventilation. In addition, maintenance of anesthesia may be accomplished with N₂O-O₂ (3:2 L/min), thiopental, fentanyl, succinylcholine 0.2 per cent in a continuous drip, and manually controlled respiration. At the end of anesthesia, the depression of respiration caused by fentanyl is reversed by the IV administration of a narcotic antagonist, such as naloxone 0.2-0.4 mg.

All patients are discharged the next day. There is no postoperative discomfort other than that associated with the use of the laryngoscope, bronchoscope, or succinylcholine.

Presence of a tracheotomy

Induction and maintenance of anesthesia in a patient with a tracheotomy are accomplished through the tracheal stoma. In the presence of lesions in the tracheobronchial tree, the tracheotomy endotracheal tube is removed and the ventilating bronchoscope, fitted to the CO₂ laser, is inserted into the trachea through the mouth. Maintenance of anesthesia is accomplished through higher flows of anesthetics via the side arm of the bronchoscope. The tracheal stoma is kept closed with moist gauze.

Venturi or jet ventilation

The great advantage of this ap-
proach is that it allows the patient to be ventilated without an endotracheal tube. When utilized properly, it affords unparalleled access to the laryngotracheo-bronchial tree for both diagnosis and surgery. Thus, it represents a marked advantage and technical advance over the inconvenience of working around a partially obstructing (visually and instrumentally) endotracheal tube, while preserving the safety of the procedure.

A stream of oxygen is directed, via variable sized needles, within the open lumen of the laryngoscope or bronchoscope. At high velocity, the jet oxygen stream is directed through the instrument and entrains room air (by a suction effect) with it. The result is a large volume of oxygen-air that is transmitted to the respiratory tree under readily adjustable pressures for adequate ventilation of the patient.

In this technique, we have used a 16-gauge jet needle for pediatric patients and a 14-gauge needle for adults. Pressure gauge settings have not exceeded 13.5 kg for adults or 9 kg for children. Using clinical movement of the chest as the primary guide—we use as low as 3.6 kg pressure in most of our pediatric cases and 9 kg in adults. These pressures are based on a two-stage reducing valve leading to a modified Speedaire Blo-Gun®.

A combination of endotracheal intubation and jet systems may be easily and alternately used to enjoy the advantages of the one to overcome the disadvantages of the other.

Complications

Carbon dioxide laser microsurgery on the larynx and tracheobronchial tree under general anesthesia was performed in 250 patients for 700 procedures. No morbidity or mortality was observed. No side effects, allergic reactions, or injuries were noticed, either to the patients or to the personnel who were handling the patients or the carbon dioxide laser equipment. However, there were four fire accidents, of which two are described.

1) A one-year-old infant girl, with a history of recurrent laryngeal papillomas that completely obstructed the larynx, was anesthetized with an uncuffed Rusch endotracheal tube inserted through the tracheal stoma. The tube was not covered with a thin self-adhesive aluminum foil. The laser beam was discharged in a continuous fashion and went through the larynx, by vaporizing the laryngeal papillomas, and was impacted on the endotracheal tube within the trachea at the level of the tracheal stoma. The tube started burning.

This situation was brought under control immediately by removal of the burning tube, which was replaced by another tube. With the aid of a bronchoscope, evidence of second-degree burn was found in the tracheal mucosa, which healed uneventfully. Inspection of the endotracheal tube showed a very small superficial burned area, 4 cm from the distal end, 1 by 0.5 cm in size.

2) A 12-year-old boy, with a history of recurrent papillomas of the larynx, was anesthetized with an uncuffed Rusch endotracheal tube inserted through the mouth. The tube was covered with a thin self-adhesive aluminum tape. The laser beam was discharged in a continuous fashion and impacted on the distal tip of the endotracheal tube; this part was not covered by aluminum tape, and a fire started.

Immediately, the burning tube was removed, and the child's respiration was continued with Venturi ventilation. The patient was bronchoscoped, and a small superficial burn in the trachea was found about 1 cm below the vocal cords. Steroids were administered. Postoperatively, the airway was adequate, without stridor or laryngeal edema. The tracheal burn healed uneventfully.

Precautions

Fewer safety measures are necessary during the use of the CO₂ laser in comparison with the ruby, argon, or
other lasers. The operating room personnel need only wear ordinary eyeglasses to protect their corneas from injury if the laser beam should be reflected accidentally from a metal surface. For the same reason, the patient's eyes must be taped shut. If an area of tissue close to the target area needs to be protected, it can be adequately shielded by covering it with moist gauze, since water dissipates the energy effectively.

All types of nonflammable anesthesia may be administered to patients undergoing laser surgery. For general anesthesia, those drugs used for high-frequency electrosurgery also may be used for laser surgery. The laser presents no electrical hazards apart from those present with the use of high-frequency electrosurgery.

If an endotracheal tube is located close to the surgical area, special care should be taken to prevent laser-beam injury to the endotracheal tube, which could burn in the presence of oxygen. As discussed, a thin metal coating, such as self-adhesive aluminum tape, will protect the tube from accidental laser impaction. We are presently studying the possible manufacture of a nonflammable endotracheal tube and production of a flexible metallic endotracheal tube.

Summary

During a 42-month period (December 1, 1971 to June 1, 1975), 250 patients undergoing 700 procedures were anesthetized at Boston University Medical Center, Boston, Massachusetts, for elective microsurgical therapy on a variety of benign and malignant lesions of the larynx and tracheobronchial tree with carbon dioxide light amplification by stimulated emission of radiation (LASER).

Induction and maintenance of anesthesia were accomplished in children with an endotracheal tube, introduced through the mouth or tracheal stoma; nitrous oxide, oxygen, halothane or enflurane, succinylcholine, and manually controlled respiration were used.

In adults, induction of anesthesia and intubation were achieved with thiopental, succinylcholine, and oxygen. Maintenance of anesthesia with controlled respiration included nitrous oxide, oxygen, enflurane, and succinylcholine; or nitrous oxide, oxygen, thiopental, fentanyl, and succinylcholine.

Recently, and in 10 per cent of the cases, the endotracheal tube was removed for 10 minutes and ventilation was managed according to the Venturi principle.

No mortality or morbidity was observed; and no side effects, allergic reactions, or injuries—either to the patients or to the personnel who were handling the patients or the CO₂ laser equipment—took place. However, in four cases the firm, uncuffed red-rubber Rusch endotracheal tube caught fire due to the continuous discharge of the CO₂ laser beam. In all cases, the fire was extinguished promptly by removal of the endotracheal tube. The patients sustained second-degree burns of the tracheal mucosa, which healed uneventfully.

REFERENCES


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This paper was presented at the New England Assembly of Nurse Anesthetists 28th Annual Meeting held in Boston, Massachusetts, March 25-27, 1975.