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Review Article

Anaesthetic complications in CO2 laser in ENT surgery

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Introduction:

The word laser is an acronym for light amplification by stimulated emission of radiation and laser technology is one consequence of Novel Prize winning in quantum mechanics, which is most important in 20th century physical sciences. The rapid advancement of this technology in ENT surgery has been accompanied by complications, making it imperative that anaesthesiologists as well as ENT surgeons understand the potential threat to their patients and themselves and be preparing to respond properly. CO2 Laser surgery in ENT is one of those surgical procedures in which the surgical risk is minimal while the anaesthetic risk is great. This is because of the general problems presented by laryngeal, pharyngeal and tracheal surgeries combined with unique specific problems of the laser.

Laser system hardware:

The essential components of a laser system include a laser medium containing the atom whose electron creates the laser light, resonating mirrors to boost laser efficiency and an energy source to excite or pump the atoms of the laser medium into producing laser light[1]. The different types of laser applied in clinical practice use a variety of laser media and energy pumps. Some clinical lasers use a gaseous medium such as CO2 and are pumped by electrical discharge[1]. CO2 lasers may produce a continuous or an intermittent pulsed beam output[2]. Because lasers are not very efficient at converting electricity into light, they require a large power supply. For example, a laser with a 10-W output requires in excess of 1000W of alternating current from a wall socket[3]. So some laser systems may require special wiring for the high current load. This electrical energy is converted to very high voltages (5000 to 30,000 V) to drive the gas discharge[3]. Many laser systems also require for cooling. Some power supply units contain compressed gas (e.g. CO2) as a laser medium as well as a coolant[3].

Clinical applications of CO2 laser in ENT:

Oral:

Leucoplakia
Verrucous carcinoma
Other carcinomas specially ca in situ
Oral and Oropharyngeal haemangiomas
Pleomorphic adenomas
Tonsillectomy
Uvulo-palato-pharyngoplasty
Benign and malignant tumours and cysts of tongue, cheek, gums and pharynx
Sub mucous fibrosis
Reduction of lingual tonsils
Elongated styloid process
Malignancies of oral cavity and pharynx

Nasal indications:

Nasal cautery
Submucosal diathermy
Partial turbinectomy
Nasal polyposis
Benign and malignant tumour of nose and paranasal sinuses
Nasopharyngeal Angiofibromas
Familial haemorrhagic telangiectasia
Choanal Artesia

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Common Laryngeal indications:

Juvenile laryngeal papillomatosis Laryngeal polyps,cysts and granulomas

Polyps or granulomas of the vocal cords

Congenital subglottic haemangioma

Benign and malignant tumours of larynx and laryngo-pharynx (both primary treatment and palliative).

Carcinoma in situ of the vocal cords

Invasive carcinoma of the vocal cords

Bilateral Abductor cord palsy

Reinke's Oedema

Laryngeal and subglottic stenosis.

Ears:

Aural Polyps, Accessory auricle, small lumps in and around the ear(soft tissue). Chondromas of the pinna.

Various miscellaneous tumours of Face/ Head and Neck vascular lesions.

CO2 Laser hazards:

The hazards associated with laser surgery can be due to atmospheric contamination, perforation of a vessel or structure, inappropriate energy transfer and many more.

Atmospheric Contamination: Laser Plume

Vaporization of tissue by laser produces a plume of smoke and fine particles that is efficiently transported and deposited in the alveoli[4]. Many individuals find the odour of this plume objectionable and sensitive individuals have described headache, tear and nausea as a consequence of inhalation. Ordinary surgical masks efficiently filter particles down to 3.0 micrometer and special high efficiency masks are more effective[4].

Tissue and vessel perforation

Misdirected laser beam may injure or even perforate a viscus or a large blood vessel (vessels > 5 mm are not coagulable by laser)[5]. Laser induced pneumothorax has been reported after a laryngeal surgery[5].

Energy transfer to an inappropriate location

All available medical laser wavelengths are transmitted through air and are well reflected by smooth metal surfaces[6]. Pressing the laser control trigger at the wrong time can deliver damaging laser light across the wound to sites at which surgical ablation was not desired or across the operating room into colleague's eyes.

Endotracheal tube fires

A feared complication of laser use during airway surgery is endotracheal tube fire. The estimated incidence of this complication during such operations is 0.5% to 1.5%[7]. Laser induces ignition of endotracheal tube, cuff or cottoonoids was responsible for most perioperative complications, followed by postoperative laryngeal web and laser related facial burns. With laser beam any hydrocarbon material, including tissue, plastic or rubber can ignite and burn, particularly in oxygen-enriched atmosphere. Fire can result from direct laser illumination, reflected laser light or incandescent particles of tissue blown from the surgical site[8]. Initially most fire is located solely on the external surface of the endotracheal tube, where they can cause local thermal destruction. If a fire is unrecognized and burns through to the interior of the tube, the oxygen-enriched gas combines with the to-and-fro gas flow due to ventilation will produce a flame, blowing heat and toxic products of combustion down to the pulmonary parenchyma. Puncture or unrecognized deflation of the tube cuff may also permit oxygen-enriched gas to flood the operative site and increase the chance of a devastating fire after a laser burst. Three strategies are used to reduce the incidence of airway fire[9]. Reduction of the flammability of the endotracheal tube, removal of flammable material from the airway by using a metallic Venturi jet ventilation cannula or intermittent extubation with or without apnoea and reduction of the available oxygen content to the minimum required for reasonable arterial saturation.

Anaesthetic problems associated with laryngeal surgery

The airway:

The anaesthetist must share the airway, which may already be compromised by disease, with the laryngoscopist. The potential for airway obstruction is therefore great. Any method of management must ensure adequate respiratory gas exchange during the entire period of surgical instrumentation of the airway.

Circulatory changes associated with laryngoscopy:

Anyone who has been involved with providing anaesthesia for laryngeal laser surgery cannot help but be impressed by the hypertensive, tachycardic response to laryngoscopy which continues as long as the laryngoscope is in place[10]. The inevitable increase in myocardial oxygen consumption which accompanies this response has been shown to produce signs of myocardial ischemia under anaesthesia in those patients with evidence of ischaemic heart disease[11].These circulatory changes must somehow be modified to prevent ischaemia from occurring.

Postoperative laryngospasm and oedema:

The incidence of postoperative laryngeal spasm after laser surgery of the larynx is high[12]. This, in addition to any oedema that may occur, has the potential for producing hypoxia in the postoperative period. A method of decreasing this incidence would of course be highly beneficial.

Operating room pollution:

The evidence suggests, but doesn't prove, that contamination of the operation theatre environment with nitrous oxide and volatile anaesthetic agents may lead to health hazards in operation theatre staff. These potential hazards include increased incidence of spontaneous abortion in females, possible congenital anomalies in children of operation theatre staff, increased incidence of liver disease and increased incidence of reticuloendothelial neoplasm[13]. For this reason, most authorities believe that these gases should be removed from or not introduced into the operation theatre environment. The anaesthetic management of laryngeal laser surgery should take this into account.

Safety precaution for operation:

1. If one can't manage, adjust or operate the laser system, harmful beam may be released. So the person in charge of handling the system must have a full knowledge of all safety regulations and operation procedures.
2. The beam radiated from the system includes visible or invisible laser beam which are harmful to eyes. Be careful not to look at the laser beam or get exposed to the reflected laser beam. Metals with an uneven surface can reflect the CO2 laser beam. All staff in the operation theatre must wear protective eyeglasses to prevent accidental exposure to laser beam. One should not look at the aiming beam directly. In addition, the aiming beam must not be directed toward the eyes. The eyes can be seriously damaged in case they are exposed to beam even though the output of the beam is at a low level.
3. Protective eyeglasses: Be sure to check whether the glasses have the function of protection from the laser with a wavelength of 10,600 nm[14]. This function is included in most protective eyeglasses having the function of protection from side exposure.

4. Patient's safety-

- cover the operative field with a wet towel
- get the patient with consciousness to wear protective eyeglasses
- cover the patient's eye with a watery eye-protector band or wet gauge piece.

5. Don't operate the system in the neighborhood of volatile materials such as inflammable anaesthetics, alcohol, gasoline or solvents. Inflammable items like cloths and surgical white coats must be kept beyond the reach of light. It is advised not to use inflammable materials and instruments, if possible. Be sure to keep a fire extinguisher near the system.
6. The body of the system generates a high voltage. In order to prevent injuries, never begin operation of the system before you check whether all panels are properly closed.
7. Use only the power supply equipment and plugs compatible with the system. Only power supply plugs which are in good condition and perfectly fit into the system must be used.
8. The system is connected by the grounding system in the power supply cord. For safe operation of the system, it is essential to have a proper grounding connection. To maintain excellent grounding condition, the power supply cord must be plugged in quality power supply equipment used for hospitals[15].
9. Rupture of endotracheal tube cuffs: The techniques of anaesthesia involving small-bore endotracheal tubes rely for adequate ventilation

on the production of an airtight seal between the cuff of the endotracheal tube and tracheal wall. The laser beam may hit the cuff by mistake, rupturing it. This will usually prevent adequate ventilation from occurring, and requires re-insertion of a new endotracheal tube. Also, it raises the possibility of a small piece of the cuff being aspirated. In the unlikely event that the rupture is not noticed (usually the loud report of the cuff breaking alerts the operating team), the consequences of asphyxia would ensue or the tube within the area of the cuff would ignite. In order to prevent or minimize these potential problems, several techniques of anaesthesia for laser surgery of the larynx have been used.

Use of small bore endotracheal tube[16]: The passage of a small-bore endotracheal tube with inflated cuff has some distinct advantages. First, the airway is ensured, allowing artificial ventilation to proceed unimpeded. Also, the cuff effectively prevents the aspiration of blood or tissue. The disadvantages are the obstruction of the surgeon's vision by the tube, especially if the lesion is posterior, and the possibility of ignition of the tube or rupture of the cuff by the laser beam. To prevent ignition of the tube, it must be wrapped with metal foil (3M aluminium tape) which may be traumatic to the vocal cords, or muslin which must be wet and bulky[17]. Rupture of the cuff can only be prevented by carefully confining the laser beam to the area of the surgical lesion. Ideally laser endotracheal tube is bi-cuffed. Distal cuff is filled with air. The proximal cuff should be filled with saline tinged with methylene blue so that the cuff is readily visible and if ruptured no oxygen will be present to support combustion of that portion of the endotracheal tube. Moreover, as there is distal cuff with air, it will give protection to airway even if proximal one is ruptured.

Injecting techniques[18]:

The introduction of jet ventilation has made it possible to achieve adequate ventilation by forcing gas under relatively high pressure through a small orifice attached to the laryngoscope blade. The obvious advantage is an unobstructed view of the surgical field. The disadvantages are that ventilation depends upon precise placement of the laryngoscope blade so that the jet of gas is directed straight between the vocal cords into the trachea. It is also quite difficult to achieve adequate ventilation in patients with COPD or those who are obese, i.e., those patients who may require high airway pressures to achieve adequate ventilation. Jet ventilation carries the risk of barotrauma to the lung

or tissues surrounding the larynx leading to pneumothorax or surgical emphysema. Under normal circumstances, jet ventilation for laryngoscopy is carried out with oxygen as the driving gas. This leads to a very high oxygen concentration around the larynx which in the face of the laser beam and a potentially inflammable substance could produce a fire involving the tissue of the larynx and trachea. This can be prevented by using an oxygen/nitrogen mixture such as air or 30 per cent oxygen/70 per cent nitrogen. In fact, a mixture of 50 per cent O2 and 50 per cent N2 has been shown to be safe.

Premedications for laser surgery of the larynx[19]:

Although drying of secretions is no longer considered routine for most surgical procedures, laryngoscopy can generate oral secretions which may interfere with visualization and make surgery more difficult. Therefore laryngoscopy should be preceded by administration of a drying agent. Glycopyrrolate which is an excellent drying agent and does not produce as much tachycardia as atropine in equipotent doses is given intramuscularly 45 minutes before the procedure. Other premedication is given according to the patient's specific needs.

Special ETT's. Some special tubes have been made to deal with the problems of flammability and cuff rupture.

- **Norton**. This spiral wound stainless steel ETT had no cuff but a separate cuff could be attached if desired. It is no longer available.
- **Bivona Fome-Cuff**. This is an aluminium spiral tube with a silicone polyurethane foam cuff in a silicone envelope. The foam is self inflating (it has to be sucked down) thus preventing deflation in the event of cuff rupture. It should nonetheless be filled with coloured saline to identify rupture. Its problem is the trauma an undeflated cuff will cause in the event of perforation. It also has a high incidence of sore throat and is only recommended for use with a CO_2 pulsed laser.
- **Xomed Laser-Shield**. A silicone elastomer tube containing metallic powder only for use with pulsed CO_2 laser less than 25W. There is still a risk of

perforation and fragmentation into silica ash and wet pledgets should be placed around the cuff.

- **Mallinckrodt Laser-Flex**. An airtight stainless steel spiral wound tube with two PVC cuffs which should be filled with coloured saline. The distal cuff maintains the seal if the proximal one is ruptured. It is only recommended for CO_2 and KTP-Nd-YAG, not the ordinary YAG.

Airway Fire Protocol

1. Remove source of fire (the laser!).
2. Stop ventilating, disconnect circuit, extubate.
3. Extinguish fire in bucket of water (MUST have one ready!).
4. Mask ventilate with 100% O_2, continue anaesthesia i.v.
5. Direct laryngoscopy & rigid bronchoscopy for damage and debris.
6. Reintubate if damage.
7. Blowtorch fire may need distal fibreoptic bronchoscopy and lavage.
8. Severe damage may need low tracheostomy.
9. Assess oropharynx and face.
10. CXR.
11. Steroids.

Conclusion: Lasers have some unique advantages in surgery. They allow precise microsurgery. The ability to focus the beam on a tiny area concentrates the intensity enormously, producing heat at a rate of many thousands of degrees in some cases, allowing precise, rapid vaporisation of tissue. Laser surgery is relatively dry, providing near instantaneous sealing of small vessels and lymphatics. There is also minimal damage to adjacent tissues resulting in less oedema, scarring and post operative pain. There are many hazards of laser surgery if anyone uses it without proper knowledge and precaution. All hazards can be prevented if laser is used in planned way. Although many laser surgeries can be performed in a clinic rather than in a hospital, the person guiding the laser must be at least as thoroughly trained and highly skilled as someone performing the same procedure in a hospital setting. The American Society for Laser Medicine and Surgery, Inc. urges that:

- All operative areas be equipped with oxygen and other drugs and equipment required for cardiopulmonary resuscitation (CPR) .
- Non-physicians performing laser procedures be properly trained, licensed, and insured.
- A qualified and experienced supervising physician be able to respond to and manage unanticipated events or other emergencies within five minutes of the time they occur.
- Emergency transportation to a hospital or other acute-care facility be available whenever laser surgery is performed in a non-hospital setting.

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