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Safety and Regulation of Medical Laser Applications – A Health and Safety Professional Perspective

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Laser safety in medical applications follows the same principles as in other laser work. The primary safety hazards are beam-related, these include eye and skin exposure to direct or reflected laser beams. The degree of hazard varies with the power and wavelength of the beam, and features of the reflective surface. The secondary safety hazards are non-beam-related. These include fire hazards due to unexpected deposition of energy with a high power density onto combustible materials in the laser beam path, and electrical hazards arising from high voltage laser equipment being used in an often wet surgical environment.

There are some unique health hazards associated with laser applications in medicine. The most prominent of these, arguably, is the laser generated air contaminants ("laser plume") arising from beam energy interacting with biological tissues. Apart from toxic pyrolytic compounds commonly found in laser plumes, some studies appear to imply laser procedures aerosolize infectious agents and cause infection in medical practitioners. Others maintain that a direct linkage between laser procedures and infection is still lacking. Regardless, laser plume should be controlled, mainly by local exhaust ventilation. A surgical-mask-type "laser plume mask" does not provide adequate protection.

In the English-speaking countries alone, there are at least three sets of well-established medical laser safety guidelines. However, there is a reasonably uniform laser hazard classification, and safety management system. China and Hong Kong have our own general laser safety guidelines. A comprehensive laser safety program includes elements on facility design, reflection control and fire safety measures, warning devices, personnel training, equipment control and maintenance, operational procedures and checklists, personal protective equipment, and local exhaust ventilation. Considering the unique conditions of medical laser applications, especially those related to surgical procedures, proper training and effective communication are among the most important elements in a medical laser safety program.

Statutory Regulation for Laser Devices

Wing-lok LO

This is a discussion on the need to regulate and control the use of laser devices, the regulatory mechanisms applicable at present, and legislative options that may be employed to strengthen control.

Laser Safety in Cutaneous Laser Surgery

Dr. K. K. LO

Cutaneous laser surgery is now a procedure widely available in many private practices and in some public institutions. There had been a lot of advances in the past decade: both theories and technologies in this applied science – laser / photo medicine. The laser device is designed to be user-friendly, more compact, versatile and affordable. The types of cutaneous conditions that can be improved by medical lasers are increasing and it is especially true in area of aesthetic laser surgery. However, one point that has not been changed from the first laser invented for medical use – the importance of laser safety. The idea of appointing a devoted staff to take the role of "laser safety officer" is an essential step to safeguard the health of all in the laser room.

Class 3 & 4 Medical lasers used to treat human skin in a clinical setting will pose the following potential hazards that had been well documented:

1. Electrical shock – electrocution and fire hazards
2. Hazardous biological fumes – potential carcinogens and infectious particles
3. Eye injury – macular injury with substantial loss of vision
4. Skin injury – hypopigmentation, scarring
5. Skin infection – reactivation of latent herpes

As a consequence, laser safety should be one of the most important factors for a practitioner to think about before setting up a laser practice. Proper training including hand on exercise with experienced laser surgeons is essential to acquire the skill and to know the risk of such procedures. Practitioners who start the laser surgery practice by self-learning without supervision are risking their careers. Prevention is better than cure. To avoid the unnecessary injury induced by lasers is easy to achieve if all laser procedures are conducted under a laser safety officer (LSO). LSO is usually an experienced nurse with proper training in institution for laser knowledge and the safety measures of laser machine operation. A LSO should be very cautious or even obsessive in examining all the safety steps in every laser surgical procedures in the laser room. He or she should be familiarized with the operation manual of the laser machine and to check all steps of safety measures before allowing the practitioners to start the procedure. The LSO in the laser room takes the authority and the role of an occupational safety officer in the workplace.

Laser Applications in Otorhino-laryngology

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Lasers have moved from the laboratory to daily conventional surgery. From the early perception of being a simple light scalpel they are now standard surgical tools with sophisticated and varied applications.

Surgery in the Ear, Nose and Throat demands selective and diverse requirements which modern lasers with different wavelengths can deliver. Pin point accuracy of the CO_2 laser with minimal bleeding and thermal damage on one end of the spectrum offers obvious benefits in the airway, the ear and even in the nose. On the other hand ablation with control of bleeding in the aerodigestive tract is achieved by using Nd Yag lasers. Delicate microsurgery in the ear has a loyal following by those that use lasers. Even endoscopic (minimally invasive) dacrocystorhinonostomy has been successfully performed with the help of lasers. Lasers are making a significant contribution to cost effective management of numerous common conditions such as snoring, nasal obstruction and sinus disease which are now being treated by ambulatory surgery. Lasers are also used to detect and destroy surface tumours in the head and neck area by activating dye concentrated in the cancer cells.

Explosion in technology has been paralleled with multiple laser applications of undoubted benefit. These must be balanced with their expense and should be used only when proven value can be shown.

Laser Applications in Ophthalmology

Wai-man CHAN

Laser has been widely applied in the field of Ophthalmology, because of its high level of precision and predictability in delivery. The direct accessibility of the intraocular structures through a transparent cornea and the extremely delicate eye tissues make laser a powerful and safe tool to be popularly used as compare with the open surgery. It can be adopted to treat a number of skin lesions cosmetically. It can recannalize occluded nasolacrimal duct. Laser is widely used in treating opened or closed angle glaucoma. It is also commonly applied in a number of retinal conditions such as retinal breaks, retinal detachment, and retinal vascular diseases.

Two areas, however, have recently received most rapid development – refractive surgery and choroidal neovascularization management.

The **excimer laser** has been used in the eye for more than 10 years because of its ability to precisely shave off or remove corneal tissue without damaging surrounding or underlying cornea. The procedure calls **LASIK** by using a cool beam of ultra-violet light that is computer controlled to reshape the cornea. The laser is extremely precise and predictable. Each pulse removes 0.25 microns of corneal tissue. How much tissue is removed is determined by the shape and prescription of the eye. The excimer laser is used to correct several refractive errors – **hyperopia** (farsightedness), **myopia** (nearsightedness) or **astigmatism**. With the advent of wavefront analysis designed to detect refractive error and aberrations of the eye, **wavefront-guided LASIK** is a promising technique that offers the potential to correct refractive errors, to improve visual acuity, and to increase the quality of vision.

Photodynamic therapy is a 2-step procedure, where light-activated drug, the photosensitizer is first to be infused followed by the application of low energy non-thermal diode laser. This treatment philosophy has been recently used to treat choroidal neovascularization (CNV) secondary to **age-related macular degeneration** (AMD) – one of the leading causes of blindness in the elderly and CNV secondary to **high myopia** – a disease with a very high prevalent in Hong Kong. The photosensitizing drug administered will bind specifically to the abnormal vessel. The drug being activated by the "cold" laser beam subsequently causes a chain of reactions. This will block the abnormal vessel selectively. The therapeutic effect is not observed until both drug and light are combined, so it can reduces the damage to the adjacent healthy tissue.

Laser Lithotripsy for Ureteric Calculi in Urology Practice

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Laser lithotripsy of ureteric calculi was first report in the late 80's. It was the pulse dye laser (504 nm) employed to fragment ureteric stones. Holmium: YAG laser (2100 nm) then came into the market in the early 90's. Since then, it has become the most widely applied armamentarium for treating ureteric calculi.

Our experience with the Holmium: YAG laser started in 1994. We report a success rate of >80% in fragmenting ureteric stones. Holmium laser is very powerful in stone fragmentation. It can be used in all type of urinary stones including the hardest oxalate monohydrate stone. However, it does impose extra risk of damaging ureteric wall and suggested its use with caution. The mechanism of laser stone fragmentation and some of the clinical experience will be presented as well.

Lasers in Gynaecology

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Many conventional surgery with the scapel can now be replaced with endoscopic technique, the CO_2 laser acting like a fine knife can be introduced via the laparoscope to replace most of the conventional microscopic reproductive surgery like ovarian salpingolysis, salpingostomy and endometrioma treatment.

The advantage of the CO_2 laser is its precision, lack of trauma with minimal reaction and subsequent adhesions.

The desired effect can be achieved by varying the wattage, spot size and focal length.

The treatment of endometriosis allows complete destruction with minimal trauma even if the endometriosis is on the bowel or bladder.

Laparoscopic uteral sacral nerve ablation (LUNA) is a simple method to treat intractable dysmenorrhoea.

The Nd. Yag laser introduced by fibres has more penetrating and haemostatic properties. It is useful for the ablation of the endometrium for menorrhagia thus eliminating the need for hysterectomy.

Although lasers are relatively easy to learn, there are problems like smoke production and evacuation, beam alignment and maintenance.

Finally, the Nd. Yag laser is being used on a cellular level for invitro-fertilization like zona drilling, assisting hatching and blastomere biopsy.

Use of Lasers in Assisted Reproduction

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Micro-manipulation of gametes and embryos has become a very important part of assisted reproductive technologies (ART). Laser technique provides a precise, fast and efficient way for the micro-manipulation.

Laser microbeam was once used to manipulate the movements of spermatozoa during subzonal sperm injection (SUZI) for assisted fertilization. With the development of intracytoplasmic sperm injection (ICSI), SUZI is not longer used in ART centers. Most of the studies of laser application in ART have focused on the treatment of zona pellucida (ZP), which is a hard layer covering an oocyte or embryo. ZP can be partially dissected with laser and this was used previously to assist the fertilization process in patients suffering from severe male factor infertility. An opening can be made in ZP of embryos, facilitating the hatching of cleaving embryos in some groups of infertile patients undergoing ART. One or two cells can be removed from the embryos through the opening in ZP for genetic analysis before transfer i.e. preimplantation genetic diagnosis. Only embryos with normal genetic make-up are transferred back to patient.

Laser has also been used to bisect ZP into two equal halves for performing the hemizona assay, which is a functional bioassay to test the binding capacity of spermatozoa to an oocyte.

Laser in Cardiology

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Laser has been used in the treatment of cardiac patients mainly in connection with ischaemic coronary syndrome, the second major cause of death in developed countries. The use of laser in the treatment of other forms of heart disease (arrhythmia, heart failure, valvular disease, etc) is far less well defined.

Ischaemic coronary syndrome is a direct result of atherosclerotic narrowing of one or more of the coronary arteries, leading to chest pain (stable and unstable angina), myocardial infarction, heart failure and perhaps death. Current treatment modalities include medical treatment and revascularization, the latter either by open-heart bypass surgery or recently by percutaneous ballooning and related procedures.

Percutaneous transluminal coronary angioplasty (PTCA) or ballooning has become the mainstay of revascularization treatment. However, it has its procedural limitation (especially in chronic total occlusion and very calcified disease) as well as a very high rate (approaching 50%) of restenosis (re-narrowing of the dilated artery in 3 to 6 months time). Other treatment options are developed to aid in achieving a higher procedural success and lower restenosis rate.

Excimer laser coronary angioplasty using directional intracoronary laser catheter has been developed for the same purpose. It is most useful in chronic total occlusion, especially in lesions uncrossable with conventional guidewire. However, it has a much higher acute complication rate than PTCA, much more expensive and difficult to use, and the restenosis rate approaches 60%. Its use is therefore only limited to chronic total occlusion and grossly calcified disease.

Intracoronary cold red laser (CRL) irradiation has been reported to reduce restenosis after PTCA by photo-remodeling of the arterial wall in animal models. However, its effectiveness in human patients cannot be adequately confirmed in our recent study at Queen Mary Hospital.

Direct myocardial laser revascularization (DMR) has received huge enthusiasm until recently in the management of terminal ischaemic heart disease with severe symptoms of angina and heart failure. This technique involves direct punching of multiple tiny channels (laser holes) into the myocardium either during open-heart surgery or by various percutaneous laser catheter (excimer, homium: yttrium or carbon dioxide laser source), hoping that new microvasculature can grow directly into the myocardium from the heart cavity, thereby supplying blood to the ischaemic area. Initial reports of alleviation of angina symptoms and improved exercise tolerance have largely been disproved by recent randomized studies. The effect is most likely psychological. In fact, DMR is no longer recommended as a treatment option by the FDA.

In summary, laser at the moment has very limited application in cardiology as compared to its vast importance in other medical fields.

Revascularization in ischaemic syndrome is still largely achieved by ballooning and related devices.

Laser Surgery for Chest Diseases

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The application of laser for management of chest diseases has lagged behind some other medical disciplines, and early experiences with the use of different lasers, most commonly carbon dioxide (wavelength 10.6 µgm), Nd-YAG (1.06 µgm, 1.33 µgm), Ho-YAG (2.06 µgm), excimer (0.3 µgm) for general thoracic and cardiovascular diseases came not from cardiothoracic surgeons, but from ENT surgeons, pulmonologists, gastroenterologists and interventional cardiologists.

General Thoracic Surgical Applications

Laser may have an adjunctive role in thoracic surgery for selected patients. There have been reports of its use in lung resections (especially when the tumor involves the chest wall), ablation of pulmonary bullae, and endoscopic relief of tracheobronchial or oesophageal obstruction. Its main advantage here is the ability to achieve haemostasis, but at the expense of high initial cost which renders laser not widely popular in mainstream thoracic surgery. Two far more attractive prospects of laser use reside in photodynamic therapy and early detection of mucosal changes in early cancers.

Cardiovascular Applications

The use of CO_2 laser in myocardial revascularization in patients not suitable for conventional coronary bypass has been a subject of intense research. Definitive evidence of its efficacy (apart from symptomatic anginal relief), however, is lacking. There have been a wealth of literature on the use of laser for tissue welding to achieve sutureless vascular anastomosis. However, this remains largely experimental and there are technical hurdles to overcome. The widest application of laser here remains catheter-based therapy like laser angioplasty.

The Application of Laser in Plastic and Cosmetic Surgery

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47830 cases of skin lesion were treated by different laser, included 46 different diseases in 12 groups. The laser were employed are VPW 532 nm laser, Q-Switched 532 nm laser, Q-Switched 755 nm laser, Q-Switched 1064 nm laser, 694.3 nm laser, 800 nm laser, 2940 nm laser, 10600 nm laser, etc. Some diseases such as nevus of Ota could be cured completely, but the vascular lesions of skin and the hyperpigmention after skin resurfacing were not satisfaction with laser up to now. The advantages or disadvantages of different laser were analyzed and some key points for laser treatment were summarized.

Cosmetic Laser Surgery

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At the present, there are six functional categories of laser systems designed for improvement of skin and facial conditions. The 6 major functional categories as well as their major medical applications are:-

I. Pigment Laser Systems

e.g. Alexandrite 755, NdYag 1064, Ruby 695, QS532, VP532, Intense Pulsed Light (filter 570/615)

- for freckles, lentigines, moles, melasma, nevus spilis, becker nevus, eyeliner, eyebrow liner, tattoo, pigmented scar.

II. Vascular Laser Systems

e.g. Pulsed dye 580/590, VP532, Intense Pulsed Light (filter 550/570), NdYTag 1064 – long pulse

- for port wine stain, rosacea, telangiectasia, reticular veins, angioma, hemangioma, active scars.

III. Non-Ablative Laser Systems
e.g. Smooth beam, Intense Pulsed Light (Photo facial), NdYag 1064 – long pulse
- for wrinkles, laxity by improving dermal collagen with minimal downtime.

IV. Ablative Laser Systems
e.g. Carbon dioxide (Ultra pulse, super pulse), Erbium, Combined CO_2/Erbium
- for deep lines, wrinkles, acne scars, deep pigment lesions, warts.

V. Hair Removal Laser Systems
e.g. Light sheer, IPL (595/645 filter), NdYag and others
- for hair removal.

VI. Incisional Laser Systems
e.g. 0.2 mm CO_2, Erbium
- assists in upper and lower blepharoplasty, hair transplantation, other surgeries.

The applications and limitations of these laser systems will be briefly discussed.

The Use of Lasers in General Dentistry

Johnny WONG

Research on the use of laser in dentistry started in the 60's. Progress was minimal due to its huge size and bulky delivery system so most of the works were done in the laboratory. With the FDA approval of the use of lasers on human soft tissue in 1992, more clinicians were involved in the research and the spectrum of use was widened.

Using lasers in dentistry revolutionized many surgical procedures, minimizing bleeding, swelling, scarring and pain. The potential benefits of using laser include procedures done on soft tissues of the mouth. Because laser techniques cause less pain than traditional methods, they are also likely to reduce the fear that many people have of the dentist. At the very least, lasers in some dental applications would eliminate the noise of the instruments that to some patients are nearly as disturbing as the physical discomfort. This lecture reviews different types of lasers used in dentistry and the comments from the users.