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Laser In Ophthalmology

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Abstract

Laser is abbreviation for "Light Amplification by Stimulated Emission of Radiation". An ophthalmic laser is a source of laser light mounted on a biomicroscope. Aimed at the eye, the laser beam causes local photocoagulation. The trace of photocoagulation of our tissue is called a laser seal. The pulse of laser light that causes photocoagulation has variable size, intensity and duration.

Keywords: *Ophthalmology, Laser, Tissue, Trauma, AMD*

Introduction

Laser (light amplification of stimulated emission of radiation) could be a term that describes the production of a fine beam of light with very specific properties [1]. The properties of any given laser emission are used to produce a certain tissue reaction for a therapeutic effect.

The application of this invasive procedure requires compliance with certain health and safety regulations, obtaining informed consent, and compliance with WHO surgical checklist for correct patient, site, and procedure verification. Some of the health and safety regulations will vary slightly between units and more so between countries.

Laser Light

Laser is an acronym for "light amplification by stimulated emission radiation" [2]. Laser produces a coherent, focused, monochromatic, high-energy type of light. Injuries resulting from the exposure of the eye to the laser light usually occur accidently. Besides, the laser light being reflected from optical interfaces like contact lenses and mirrors within the rooms of photocoagulation may result with phototoxicity for the patients and patients' relatives and even the physician who are present within the said room. Lasers which are utilized in the industry and for military purposes also are risky for the working employees.

Exposure of the eye to the laser light will cause different results according to the laser type and wavelength. At low-energy-level lasers emitting within the far ultraviolet, UV and visual spectrums induce a photochemical reaction that breaks molecular bonds like femtosecond lasers. Accordingly, those forms of lasers cannot reach inner coatings of the globe and people don't seem to be expected to cause any damage. The lasers, with higher energy levels may emit the visible light which is absorbed by retinal pigments. and people are dissipated as heat through molecular collision and results in photocoagulation, like argon lasers. Exposure of the aforementioned form of lasers accidentally induces damages within the posterior segments of the world whose treatments are impossible.

Several reports of accidental laser burns of the inner coatings of the eye have appeared within the literature. In these publications, macular oedema, perifoveal haemorrhage and macular hole, subhyaloid haemorrhage and RPE degeneration are considered among the clinical signs seen within the posterior segment after the laser exposure.

When the histopathology of the damage induced by the argon laser photocoagulation is examined, it'll be observed that the target tissue is that the retina pigment epithelial cell and outer segments of the photoreceptors. It's observed that especially the outer segments of photoreceptors are detached from the retina pigment epithelium which chorioretinal atrophy developed during this area afterwards. This process changes proportionally with the duration of laser exposure and therefore the laser power. For instance, while only retina pigment epithelium and outer segments of photoreceptors are affected just in case of low level of energy and mild exposure, full-thickness damage which can cause iatrogenic hole within the retina along with the damage of Bruch membrane and choriocapillaris can occur just in case of high level of energy and exposure.

Energy

Subatomic particles in any given medium (in this case, a given gas, liquid, or solid) exist in a ‘resting’ state [1]. Delivery of energy to the medium excites these particles momentarily to the next energy level. Their return to the resting state is accompanied by release of energy. Collection of those small ‘packets’ of energy (usually mentioned as photons) ends up in a coordinated emission that has specific physical properties. The 2 most vital physical properties of this emission are its temporal and spatial coherence. Its temporal coherence means it's monochromatic (almost the identical wavelength throughout) and longitudinally in phase (its sub-waveforms remain in phase over distance). Its spatial coherence allows it to be used to generate a very narrow beam with minimal divergence over distance.

There are three generic components required to provide a laser emission: (1) laser medium; (2) excitation mechanism; and (3) feedback mechanism.

FSL

The femtosecond laser (FSL) may be a solid-state laser that produces infrared light pulses with a wavelength of 1030–1060 nm, and a duration of 300–800 fs [3]. The energy range per pulse is usually 5–10 microjoules (μJ). The photodisruptive effect is achieved when the FSL beam is sharply focused and generates plasma within the affected tissue. This plasma rapidly expands as an acoustic shock wave, displacing the surrounding tissue. Cooling of plasma results in formation of cavitation bubbles. Photodisruption occurs at the laser's focus with none thermal effect or collateral tissue damage.

The FSL can create tissue separation and precise cuts within the cornea, lens capsule, and crystalline lens. Important features of any femtosecond laser are the repetition rate and therefore the numerical aperture. Higher repetition rates lead to less energy required to get the identical tissue effect. The numerical aperture indicates what proportion concentrated energy is at the impact area. A bigger numerical aperture causes less dispersion of the laser beam and thus better focussing and/or smaller spots. This leads to improved precision of the cut depth and lower energy, to provide the identical tissue effect. Therefore, corneal treatments require a bigger numerical aperture (with a lower energy level), while vice versa holds true for the crystalline lens.

Trauma

Even a relatively low-output laser can produce serious eye injury, because the eye focuses the parallel beam and increases the focal retinal irradiance by a factor of over 100,000 times above that incident at the cornea [4]. Highpowered lasers are in use by the military for many years. There are reports of unintentional injuries from 1960s onwards and reports of adversarial use from 1980s. The consequence of those events was the 1995 Protocol to the geneva convention which specifically regulates laser use to decrease the chance of deliberate injury and bans the use of lasers designated to be blinding weapons.

The risk has not been eliminated. Pilots were attacked with laser targeting designators in Bosnia within the late 1990s. With relatively cheap, readily available, and simply portable devices available to insurgents, terrorists, and criminals, increasing numbers of incidents are occurring.

Pressure

Full blown primary acute angle closure glaucoma is simple to recognise [5]. The patient presents with a red eye, reduced vision with haloes, severe pain and a middilated fixed pupil. Problems however can arise if the systemic symptoms related to the rising pressure overwhelm the local symptoms and also the patient is directed to the incorrect department. Such patients is also found by the ophthalmologist because the vomiting patient in gastroenterology, the severe headache patient in neurosurgery or the confused photophobic patient in neurology, all with an apparently incidental red eye. the end result depends on the duration of the raised pressure before it's controlled, instead of on the amount of intraocular pressure recorded at the time of diagnosis and for that reason prompt action is necessary for a good visual outcome.

Once the pressure is controlled, gonioscopy should be repeated, or done for the first time if not possible initially, and laser peripheral iridotomy (PI) should be carried out within the next 24 hours within the fellow eye and within 48 hours within the affected eye depending on the clarity of the cornea. Note that if significant pressure is exerted on the eye with a gonioscope, the angle may appear open when it's functionally closed or closeable. Raised IOP (intraocular pressure) thanks to plateau iris may or might not reply to PI alone. If it doesn't, referral to a glaucoma surgeon for further laser or intraocular surgery, probably lens extraction, is necessary. Anterior segment OCT is that the best method for assessing the anatomical configuration.

If the IOP has not come down with treatment, there could also be a very large lens or subluxed lens causing pupil block, or ciliary block. Ciliary block occurs when aqueous is misdirected posteriorly with anterior displacement of the lens and iris. It occurs after intraocular surgery, usually in eyes with a previously narrow angle. it's treated with intensive dilatation with atropine 1% and phenylephrine 10%. Pilocarpine must be avoided. Otherwise the identical measures as used for acute angle closure are aimed at reducing pressure, but if they fail, the anterior vitreous face must be disrupted either by YAG laser or surgically.

AMD

Notwithstanding the progress in surgical intervention over the last few decades, cataracts are the main reason behind visual defect in all the world except the most developed countries [6]. The rapid advances in surgical techniques and modern instrumentation have modified cataract removal from intracapsular to extracapsular extraction with lens system implantation and facoemulsification, dramatically reducing postsurgical recovery and improving the quality of vision. Another major reason behind low vision within the elderly is open angle glaucoma. Diagnosis is predicated on pressure measurement, detecting changes within the optic nerve head and demonstrating visual field alterations by visual field testing. Early glaucoma detection and treatment significantly delay the progression of disease, reducing the irreversible damage to optic nerve fibers. Topical medication to cut back pressure level is that the mainstay of management. at this time topical acetazolamide and prostaglandin molecules are commonly used. surgical operation is reserved for cases with poor response to topical drugs and progression of disease with elevated pressure level and optic fiber damage. Age-related macular degeneration (AMD) has several forms. Wet AMD is caused by choroidal neovascularization and if unrecognized and untreated may end up in rapid deterioration of vision. Initially laser photocoagualtion was the only clinically proven management in neovascular AMD. nowadays veteporfin therapy with photodynamic treatment is employed in patients with predominantly classic subfoveal choroidal neovascularization. Dry AMD is that the commonest form and tends to progress more slowly compared to the wet form. The foremost advanced type of AMD, geographic atrophy, also causes sight loss. Early detection and prompt treatment will help optimize treatment outcome. New sorts of treatment of wet AMD like injecting antivascular endothelial growth factor, pegaptanib (Macugen) e Avastatin, have effectively reduced the progression of disease in some randomized trials. Vision loss from diabetic retinopathy may result from several diabetes related retinal changes but early recognition and treatment, including laser therapy, can prevent blindness. The retinopathy depends on the duration of hyperglycemia instead of age. Therefore, prevention emphasizes the necessity for blood glucose level control to reduce the incidence, progression, and severity of diabetic retinopathy. Degenerative myopia is another reason behind visual defect not only within the elderly but also within the younger population. Total refractive error correction and healthy nutrition are fundamental in reducing the progression of degenerative retinal alterations.

Glaucoma

Acute angle-closure glaucoma requires prompt diagnosis and treatment to preserve vision [7]. The definitive treatment requires laser peripheral iridotomy, within which a laser is used to make a synthetic opening within the iris to release the “pupillary block” (which will have to be performed on the man eye to prevent any possibility of acute angle closure in this eye). The keystone of treatment within the emergency department is medical management to acutely lower intraocular pressure. this is often accomplished via multiple modalities which usually utilize a mix of carbonic anhydrase inhibitors, beta-blockers, miotics, and hyperosmotics which serve to (1) decrease production of humor, (2) increase outflow of aqueous humor, or (3) decrease volume of vitreous humor.

Intraocular pressure should be checked 30–60 min after initiation of medical treatment in order to make sure improving intraocular pressure. These patients require a comprehensive eye examination and prompt ophthalmological consultation. Often times, iridotomy is delayed secondary to corneal edema, and medical therapy is initiated to lower the intraocular pressure acutely; however, iridotomy should be performed as soon as possible. Analgesics and antiemetics should also be used symptomatically in these patients.

Refractive Error

There is a necessity for more permanent and convenient solutions for the correction of refractive error as an alternate to spectacles or contact lenses (rigid gaspermeable, soft and orthokeratology lenses) [8]. Currently, there are alternative technologies available to treat all sorts of refractive errors and this section deals with people who involve the cornea. Technologies that address this demand will be categorised broadly into two groups: those who remove corneal tissue to correct refractive error (subtractive) and people technologies that add to corneal tissue to realize a correction (additive). Subtractive solutions, like the laser-based procedures, are non-reversible within the sense that tissue is permanently removed. The excimer laser is employed to flatten the cornea within the treatment of myopia, to steepen the cornea to correct hyperopia, and to reshape the corneal topography within the treatment of astigmatism. Depending on the sort of laser used, the corneal epithelium may need removal or lifting and replacement to show the stroma for the laser ablation and this has given rise to the development of a variety of associated surgical techniques. Newer laser technologies like the femtosecond laser are ready to pass through the tissue to the target area with apparently minimal damage and thus leave the epithelium intact. Additive solutions embrace a range of intracorneal devices made of either biological or synthetic materials or a mixture of both, which are technically removable and are therefore reversible procedures. There's some cross-over between these groups, since all devices require some kind of surgical procedure to implant them. Frequently, surgical techniques that have been developed to enable laser procedures are used for implanting intracorneal devices.

PDT

PDT (photodynamic therapy) describes the laser stimulation of a photoactivated dye that ends up in the destruction of CNV (choroidal neovascularization) [9]. This method aims to selectively destroy the membrane, while minimizing damage to adjacent structures.

The commonest indication has been for AMD, but it's also been used for other CNVs, e.g., in myopia, inflammatory membranes, etc. Its role as one agent within the treatment of CNV has now been largely replaced by anti-VEGF therapies, but it appears to be finding a brand-new therapeutic niche in diseases like CSC (central serous chorioretinopathy), PCV (polypoidal choroidal vasculopathy; passenger-carrying vehicle), and in treatment of certain ocular tumours (e.g. choroidal haemangiomas).

Verteporfin could be a photoactivated dye that binds to lipoproteins and becomes concentrated within the proliferating vascular bed of the CNV. Laser light of 689nm wavelength is directed onto the CNV, activating the dye. the quality energy level used for tumours or AMD/polypoidal lesions (600mW/cm2 × 83s = 50J/cm2) is simply too low to cause thermal damage but is sufficient to activate the dye that catalyses the formation of the free radical 'singlet oxygen'. This causes local endothelial cell death and occlusion of the blood supply to the CNV.

Tissue

Less than 10°C rise in temperature of the laser-absorbing tissue over a period of some seconds to minutes causes heat-induced cell damage or death without causing structural alterations to the tissue [10]. The time scale for large-scale protein molecular rearrangement, like folding or unfolding, is on the order of milliseconds to seconds and laser-induced heating to such time scales can cause photothermal denaturation. The damaged molecules could also be biochemically active and react with other chemicals within the cell to supply secondary damage. A 20–30°C rise of temperature over time periods ~ 1 s causes photocoagulation (denaturation of tissue proteins) through a cascade of chemical changes initiated by interaction of laser with specific biomolecules within the cells. Receptor photopigments, retinal pigment epithelial (RPE) melanin granules, and RPE lipofuscin granules can undergo photochemical reactions on laser exposure, these reactions involving free radicals and active oxygen species. It's been experimentally proven that melanin from RPE cells formed free radicals during illumination as identified by their rapid oxidation of ascorbic acid added as a marker. Free radicals and secondary active oxygen species can damage intracellular components within the absence of radical scavengers. Free radicals are known to promote inflammation in tissues. The inflammation triggers neovascular events by stimulating cell proliferation in fibroblasts and RPE cells, two cell types implicated within the recurrence of neovascularization within the eye.

From microsecond to nanosecond exposure times, RPE damage is induced by intracellular microbubble formation round the melanosomes inside the RPE cell. These bubbles expand and collapse rapidly and generate plasma that may disintegrate the RPE cell structure or disrupt the cell membrane. At subnanosecond exposures, other nonlinear damage mechanisms appear, like shock waves and laser-induced breakdown. Very rapid temperature rise can cause nonlinear effects like photovaporization, that is, explosive vaporization of tissue. Rapid pulsing of laser at rates of picoseconds or nanoseconds can cause mechanical damage thanks to rapid heating with no interval for warmth dissipation. Such nonlinear processes that occur above a certain (“optical breakdown”) threshold of irradiance are difficult to predict and may cause severe damage including retinal perforation, disruption of choroidal blood vessels with subretinal hemorrhage, and in severe cases, vitreous hemorrhage.

The photo-thermal effect of laser on tissue is employed in ophthalmology to treat retinopathy and macular degeneration maladies of the eye. Pan Retinal Photocoagulation (PRP), for instance, relies on the photothermal effects of laser. During PRP, the laser beam is concentrated on one or more spots on the retina to cause a controlled burn or photocoagulation at that spot. Since at ~60°C, the retinal region must physiologically deal with temperatures almost twice that of the core body temperature of 37°C during such laser treatment. the risk of laser PRP treatment is that visible and near-IR radiations can damage the retina in doses at or above a certain threshold value. When an intense and collimated laser beam is targeted on a specific spot on the retina, the irradiated spot will be heated to temperatures beyond that required to coagulate the diseased tissue. This is often true even with low-power lasers; a 1 mW (0.001 W) laser may result in an exceedingly retinal irradiance (energy per measure per unit area) beyond 300 W/cm2 when incident on the retina as an intensely collimated beam. Overheating could disrupt cellular mechanism in regions adjoining the target retinal zone, leading to damage to the retina. Limited blood flow within the eye aggravates this case. Local transfer of warmth to surrounding healthy tissues during retinal photocoagulation may cause rupture of Bruch's membrane with choroidal hemorrhage, or damage to the nerve fiber layer.

Conclusion

Today, eye treatment is focused on minimal invasiveness, ie minimal trauma, which is significantly helped by the use of lasers. The laser is a non-contact surgical instrument, an alternative to the traditional scalpel with many differences and specifics. It acts on tissue and pathological processes without touching or manipulating tissues. The method is sterile, non-invasive, and allows access to internal organs through optical leads and mirrors. The laser beam acts hemostatically and lymphostatically. Ophthalmology is the first branch of medicine to begin with the use of laser beams in the treatment of a number of eye diseases.

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