LASERS & ITS APPLICATIONS IN OPHTHALMOLOGY

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An acronym for LASER , Light Amplification by Stimulation Emission of Radiation was first coined by Gurden Gould. In 1916,Albert Einstein laid the foundation for invention of laser. The first working laser in Ophthalmology was made by Theodore Maiman in 1960. He utilized pulsed ruby laser coupled with monocular direct ophthalmoscopic delivery system.

Properties :

Monochromatic: having one colour/wavelength.

Coherence: spatial & temporal. The light from a laser is said to be coherent, which means that the wavelengths of laser light are in phase in space & time.

Collimation. Ordinary light can be a mixture of many wavelengths. **Directional**: laser light is emitted as a narrow beam as compared to ordinary light from light bulb is emitted in many directions away from source. Due to all these properties laser light can deposit a lot of energy within a small area.

How LASER works ? : All lasers in use require 3 basic elements:

1) An active medium that emits coherent radiation
2) A means of energy input known as pumping
3) The opportunity for oscillation & amplification through optical feedback.

Principle: Radiation emitted by spontaneous emission (Bohr's model) occurs randomly in time, but radiation emitted by stimulated emission (Einstein) is in phase with the stimulating wave & is therefore coherent.

Effects of Lasers : Laser tissue interactions :

Photothermal	Photochemical	Mechanical
⇩	⇩	⇩
Photocoagulation / Photovaporization	Photoradiation/ photoablation	Photodisruption
E.g Argon,Krypton,Diode , Nd:YAG crystals	E.g Excimer(193nm)	E.g.Femtosecond(1053nm)

Mode of operation : which depends on :

Laser material used & mode of excitation of material.

Types of Modes :

- Continuous wave operation
- Conventional pulsed operation : Q switched & Mode locked

Continuous wave operation :

Output is relatively constant with respect to time.

*DNB, RIO,IGIMS,Patna

It delivers overall more total energy & less power.

Delivers Energy over a relatively long period (fraction of sec. to a sec.).

e.g Argon, Krypton etc.

Conventional pulsed wave operation :

Mode locking is a technique by which laser can be made to produced pulses of light of extremely short duration, in order of picoseconds $10^{-12 sec}$ or femtoseconds $10^{-15 sec}$

APPLICATIONs :

Lasers in Glaucoma

Angle-closure glaucoma is usually due to pupillary block between the lens and iris. This prevents aqueous from following its normal course through the pupil to the angle & Schlemm's canal & out of the eye. Pupillary block results in the peripheral iris being pushed against the cornea, there by blocking off the angle. Therapy is directed towards creating an internal bypass with an opening in the iris between anterior & posterior chambers. Before lasers, this was achieved by a surgical iridectomy, but now the laser has all but eliminated this procedure. An iridotomy is created by the absorption of irradiated light by the melanin in the iris, resulting in a thermal effect with disruption & hole formation.

Lasers in Diabetes

Diabetic retinopathy is broadly divided into nonproliferative & proliferative types. In the nonproliferative type consist (venous dilation, aneurysms, hemorrhage, edema, exudates). These five stages can then be classified on ETDRS. Proliferative retinopathy includes the production or proliferation of new tissue, supportive or neovascular in nature in the chorio-retinal area secondary to retinal hypoxia. These include neovascularization at the disc &/or retina, glial proliferation & vitreoretinal traction. The basic rationale of laser photocoagulation is to destroy neovascular complexes, to obliterate areas of micro infarction or capillary closure, to destroy leaking vessels in the macular & paramacular region & to produce a chorio-retinal adhesion that will resist the later ravages of increasing vitreoretinal traction. The proliferation of neovascular tissues is probably the result of localized hypoxia in the region of the retinal vessels near the internal limiting membrane. It would seem that these blood vessels are proliferating in response to some biochemical substance. Intravenous fluorescein angiography consists of injecting sodium fluorescein into the antecubital vein & recording the results photographically at intervals of 0.6 to 0.8 seconds. All abnormalities of the retinal circulation can be seen & treated accordingly.

Panretinal photocoagulation appears to successfully obliterate or cause the regression of neovascularization by one of four mechanisms: the reduction or destruction of areas of hypoxic retina that are producing the vasoformative factor that causes neovascularization from healthier areas of the retina; adherence of retina to choreocapillaris (choroid), allowing more oxygen from choroid to retina; destruction of infarcted areas of retina, allowing more blood to the healthier retina; destruction of leaking vessels & abnormal vascular complexes, which normalizes blood flow to the macular area. The panretinal photocoagulation(PRP) is conducted in three to six stages in approximately two to seven days. Coagulation of 100 to 200 microns in diameter with power intensities from 100 to 400 mw & exposures of 0.05 to 0.2 seconds with sites increasing as one treats the more peripheral retina.

Posterior Capsulotomy

One of the most common uses of the Nd-YAG laser is to perform a posterior capsulotomy. There may be less incidence of edema of the macula (cystoids maculopathy) & decreased retinal detachments with the extracapsular method, which also allows for the insertion of a posterior chamber intraocular lens vs. anterior chamber lens. This again is not clear cut, but it may be more physiological in the posterior chamber & there may be less long-term corneal complications. One of the problems with the extracapsular technique is that the capsule sometimes becomes opaque. Before the YAG laser this had to be dealt with surgically, but now can be done with the ionizing effect of the YAG.

Retinal Tears

The symptoms that may occur with retinal tears are variable & include floaters, sudden showering of spots & opacities, lightning flashes, & blurring of vision. The problem with retinal tears is akin to a tear in the vinyl lining of a swimming pool. Water will eventually seep under the lining & lift the lining off. If the tear is diagnosed early before the retina has lifted, detachment can be prevented by scarring down the retina surrounding the tear. This may be accomplished by using a laser usually the argon laser. If detachment has occurred, then the retina has to be drained & a buckle placed around the sclera. Most floaters are indicators of vitreous degeneration, but a sudden onset probably should be assessed for retinal problems.

Macular Disease

Serous retinal pigment epithelial detachments are round or oval domed elevations of the retinal pigment epithelium. Fluorescein dye will readily collect there. These serous detachments can occur with or without subretinal neovascularization/CNVM . The treatment of the serous detachments without neovascularization is controversial. One prospective study found that argon laser treatment was of no benefit & perhaps harmful. Clinical signs of a subretinal neovascular membrane are a greyish or green pigmentation deep to the retina, subretinal or retinal hemorrhage, hard exudates & subretinal fluid. The membrane is then outlined by fluorescein & its distance from the fovea is measured. There is a foveal avascular zone measuring 400 microns in diameter which cannot be treated with laser as it may obliterate central acuity. Therefore, if the membrane is 200 microns or more from the center of the fovea, the entire membrane should be treated with laser photocoagulation. The most common scenario is that the patient comes to see the ophthalmologist after losing central acuity in one eye & there is no treatment due to scarring following hemorrhage, serous detachment with neovascularization or atrophic degeneration. It is important to advise the patient to monitor the fellow eye daily (by Amsler grid testing) with a view that if subretinal neovascularization should develop, it may be amenable to laser therapy .

Cataract surgery

Cataract surgery has been performed for over two millennia, but advances in technology have transformed the fundamental procedure only over the past 40 years. The use of ultrasound vibration to remove cataracts through a small incision was pioneered by Charles Kelman in the 1960 & the technique has been developed to become the standard procedure for most cataract extractions in developed countries. The Kelman phacoemulsification procedure has also become the main frame work upon which innovations in cataract surgery are built. Such innovations are driven by the need for less trauma during surgery & faster visual recovery after surgery. Surgeons have strived to reduce incision size, heat, intraocular turbulence & fluid level in order to achieve these objectives .Ultrasonic phacoemulsification probe tips tend to create relatively high levels of heat within the eye, resulting in the possibility of injury to the cornea such as corneal burns & endothelial damage. Technological advances over the past decade have reduced the effective energy liberated by the probe, chiefly through using ultrasound energy more efficiently.Perhaps the most promising front in a traumatic phacoemulsification surgery is the application of the yttrium-aluminum-garnet (YAG) laser towards emulsifying the cataract. The first laser procedure for cataract surgery was reported in 1975 by Krasnov, who used a technique called "laser phacopuncture" to make microperforations on the anterior capsule. These pores then allowed the release of lens material into the anterior chamber, which would be theoretically resorbed over time. Krasnov's Q switched ruby laser technique had limited application, since the micropores would only allow the release of very soft cataracts. Furthermore, patients had to be maintained on dilator drops for extended periods to prevent the puncture sites from closing & steroid drops to reduce anterior uveitis that inevitably occurred from the released cataract in the anterior chamber. Additional experiments with laser cataract surgery occurred with excimer lasers, most notably the 308 nm laser. The xenon chloride 308nm laser was introduced in the late 1980s, but was abandoned for cataract surgery due to concerns over retinal toxicity. The neodymium:yttrium-aluminum garnet (Nd:YAG) laser was used successfully to perform posterior capsulotomy in 1980. The YAG laser gained wide acceptance among surgeons as an excellent method of treating posterior capsular opacification after cataract surgery. The popularity of the Nd:YAG laser in posterior capsulotomies motivated researchers to explore how the YAG laser could be used to treat cataracts. A technique called laser photofragmentation, which uses the Nd:YAG laser to soften the nucleus before phacoemulsification, was explored in the mid-1980s. This procedure did reduce phacoemulsification power & time, but also increased the risk of capsular perforations.

The YAG laser has the potential to dramatically reduce the energy required to perform cataract surgery. Two types of YAG lasers are being developed for cataract surgery: the neodymium:YAG (Nd:YAG) & Erbium:YAG (Er:YAG) laser. The pulsed Q switched Nd:YAG laser, which emits at 1064 nm, does not produce direct laser light at the tip; instead, it generates shock waves through a titanium block at the tip to photolyse the cataract. This technology produces negligible heat at the tip & therefore does not require a cooling sleeve to avoid corneal burns. Consequently, incisions as small as 1.25 mm can be used to perform the procedure. Laser emulsification is relatively short for most cataracts, but can take over 10 minutes for nuclear sclerosis over 3+. Another Nd:YAG laser, which uses photoacoustic ablation under aspiration, delivers energy through a skishaped distal tip to create a "photon trap". This technology is most useful for softer nuclear sclerosis. The Er:YAG laser, which emits at 2940 nm, relies on its infrared spectrum wavelength in cataract surgery. At this wavelength, the laser produces cavitation bubbles that collapse slowly in the cataract & very quickly in water. This leads to propagated energy within the lens, allowing the laser to emulsify the material efficiently without producing thermal energy. The laser can be used with a prechopper to reduce the operating time.

Each of these YAG laser technologies can be coupled with standard I/A pumps to allow a lenticular emulsification with little or no thermal energy. The technologies open up the possibility of performing cataract surgery through very small (<2mm) incision sizes, intraocular lenses to fit through such small openings are being developed rapidly.

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