Review article

Lasers in glaucoma

Kumar S, MS
Professor, Department of Ophthalmology, Subharti Medical College, Meerut, India

Abstract

Use of lasers in the treatment of various types of glaucomas is an important aspect in ophthalmic practice. Both Argon and Yag lasers are now–a–days commonly used in the treatment of angle-closure and open-angle glaucomas. Besides this, more recently, Diode lasers are being used for the treatment of the glaucomas. Lasers are also being used in the management of intractable glaucomas which are not controlled by medication alone. In this review article, all these features have been highlighted.

Keywords: Lasers, glaucoma

Introduction

The selection and proper use of ophthalmic lens systems require both familiarity with the types of laser instruments and basic knowledge of the biophysical mechanism by which lasers exert their effects on ocular structures. Thus an introduction to laser-tissue interaction is essential prior to discussing the application of lasers in the management of glaucoma.

Laser interactions

In general, molecules in biologic tissues are opaque to ultraviolet radiation at wavelengths shorter than 300 nm and have strong vibration absorption bands for infrared radiation at wavelengths greater than about 1000 nm (Hillen, 1980). Between 300 and 400 nm, only a limited number of biomolecules have moderate absorption. Most biomolecules, however, are effectively transparent between 400 and 1000 nm. Differences in the spectral absorption properties of different molecules permit selective damage to specific components of a target tissue. Laser effects in biologic tissues may be divided into three general categories (Mainster, 1989):

Received: 23.10.2009 Accepted: 05.11.2009
Correspondence and reprint request to:
Dr Sandeep Kumar, MS (Ophthalmology)
Department of Ophthalmology
Subharti Medical College,
Meerut, India
E.mail: sandeep_65@yahoo.com
Phone: 0091-9899086466

1. Photochemical, 2. Thermal and 3. Ionizing.

1. Photochemical effects

In these reactions, photon absorption by outer electrons is needed to provide the excited molecular electronic state from which the chemical reaction can occur.

A) Photoradiation: A hematoporphyrin derivative (HpD) is selectively taken up and retained by metabolically active tumor tissue, predisposing this tissue to photochemical damage if the tumor is subsequently irradiated with light between 625 and 635 nm. The exposure of photosensitized tumor tissue is termed photoradiation therapy (PRT). Current clinical ophthalmic PRT studies are directed towards the treatment of large choroidal melanomas, which are exposed at 630 nm red light from a rhodamine B dye laser 72 hours after intravenous HpD administration (L' Esperance FA Jr, 1983). This irradiation produces an excited state of porphyrin, which interacts with oxygen to produce cytotoxic singlet oxygen. The gold laser producing 628 nm red light is a potentially useful alternative light source for PRT.

B) Photoablation: Excimer lasers producing ultraviolet light below 300 nm can provide precise corneal incisions to predetermined depths (Trokel *et al* 1982). This process may be termed photoablation, as photochemical reactions at the target site not only fragment exposed molecules but also volatilize them.

2. Thermal effects

For irradiances and exposure duration similar to that used for photochemical effects, laser radiation at longer wavelengths generally produces thermal effects. Thermal effects occur when photon absorption by outer electrons or molecular vibrations produces enough temperature rise to denature biomolecules by breaking the weak van der Waals forces that help to stabilize their complete structures.

A) Photocoagulation: Closure of blood vessels by photocoagulation is caused by light absorption in a blood column, which heals the hemoglobin to a temperature high enough to produce thrombus formation and collagen shrinkage in the walls of blood vessels and its surrounding connective tissues (Gorisch *et al* 1982). This process is known as photocoagulation.

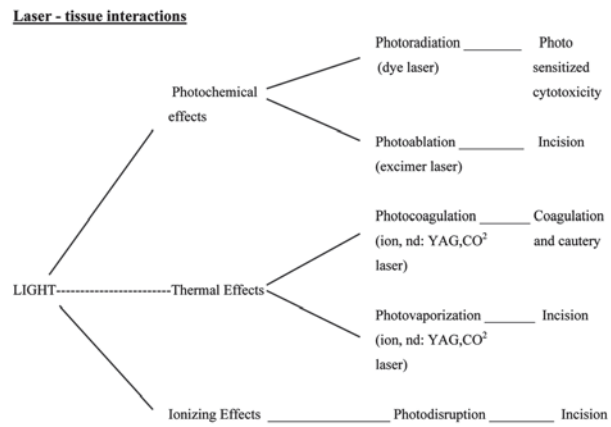
B) Photovaporization: If very high laser irradiances are used, tissue temperature can quickly reach the boiling point of water, and rapidly expanding water vapour will cause tissue disruption (photovaporization) before denaturation can cauterize the tissue. In most situations, however, photovaporization (cutting) is accompanied by photocoagulation (cautery). For example, in CO_2 laser surgery, cautery during incision can provide a virtually bloodless operating field (Beckman & Fuller, 1979).

3. Ionizing effects

At very high irradiances, generally produced by exposure durations shorter than 20 nanoseconds, enough energy is provided to tear electrons from atoms and molecules, thereby ionizing them and inducing secondary mechanical effects.

Photodisruption: Short pulse Nd: YAG lasers disrupt transparent tissues by delivering enormous near infrared (1064 nm) irradiances to tissue targets (Fankhauser F, 1981). The high irradiances ionize material in a small volume of space at the focal point of the laser beam, disintegrating it into a collection of ions and electrons called plasma. Once formed, the plasma first absorbs or scatters radiation arriving later in the pulse, thereby shielding underlying tissues, and then the plasma expands rapidly, producing shock and acoustic waves that mechanically disrupt tissues adjacent to the region of disintegration.

Laser - tissue interactions



Laser treatment in narrow angle-glaucoma

Laser iridectomy

It consists of putting a penetrating/punch burn on the surface of iris tissue to produce a full- thickness hole in the iris.

Historical perspective

In 1956, Meyer-Schwickerath first reported the creation of patent iridectomy using xenon arc photocoagulator. In the early 1980's, argon laser iridectomy became the procedure of choice for performing an iridectomy in an angle-closure glaucoma (Ritch *et al* 1989). More recently the neodymium : YAG (Nd: YAG) laser, which causes mechanical disruption of tissue, has been used safely and successfully to create iridectomies in both darkly and lightly pigmented irides (Beckman, 1971).

Indications

1. Acute angle closure glaucoma due to pupillary block: Laser iridectomy should be performed after the acute attack has been terminated with medical therapy and the eye is no longer actively inflamed.

2. Chronic angle closure glaucoma: Even if the angle appears completely sealed by PAS pre-operatively, areas of functional meshwork may open after laser iridectomy. After elimination of chronic pupillary block by the iridectomy, evaluation of the chronic angle-closure is simplified.

3. Partial thickness surgical iridectomy.

4. Prophylactic laser iridectomy of the other eye in patients with acute or chronic angle closure glaucoma.

5. Aphakic or pseudophakic pupillary block: In some cases, pockets of aqueous humour and vitreous may both be present posterior to the iris, or broad areas of vitreous may be adherant to the posterior iris. An iridectomy made over an area of vitreous iris adhesion or apposition will not relieve the pupillary block. Multiple iridectomies may be required before a pocket of aqueous humour is located and block relieved.

6. Before laser trabeculoplasty: If the narrow angle prevents visualization of angle structures, laser iridectomy may be performed on the basis of relative pupillary block, often suggested by a peripheral bombe configuration.

7. Eyes with narrow angles and positive provocative test.

8. Eyes with spontaneous appositional closure in the presence of a normal intraocular pressure.

9. Nanophthalmos: These eyes are at a considerable risk for developing angle-closure glaucoma because of anterior chamber crowding.

Contra-indications

Moderate corneal oedema
Corneal opacification
Flat anterior chamber
Completely sealed angle

Angle closure caused by primary synechial closure of the angle, such as occurs in uveitis, neovascular glaucoma or irido-corneal - endothelial (ICE) syndrome.

Preoperative treatment for laser iridectomy

Topical anaesthesia is required preceded by constriction of pupil maximally by one to two drops of 2 % - 4 % pilocarpine topically and preoperative anti-glaucoma treatment in patients with raised intra-ocular pressure.

Argon laser iridectomy

A site about two-thirds to three-fourths of the distance from the pupil to the iris root should be selected. Iridectomy is best placed between 10:30 and 1:30 positions. Avoid the 12 O'clock position.

Perform iridectomy in the base of the iris crypt, where the stroma is thinner. An arcus senilis should be avoided. Place under the upper lid as it is advantageous from an optical point of view to minimize glare and diplopia. Aiming the beam away from the fovea is extremely important in limiting the extent of retinal damage. The beam should be perpendicular to the contact lens surface to maximize energy delivery.

Generally, medium brown irides are the easiest to penetrate by argon laser, whereas light blue and dark brown irides are the most difficult to penetrate.

Neodymium: YAG laser iridectomy

Settings for Nd:YAG iridectomy have varied from one to four pulses per burst and from 1 to 10 millijoules per burst (Klapper, 1984). One should begin with a single pulse at about 1.5 to 3 millijoules. Nd:YAG laser produces equivalent or fewer of adverse effects when compared with fellow eyes treated with the argon laser. A consistent finding, however, is the occurrence of self -limited bleeding from the iridectomy site. Another complication of Nd:YAG laser is the possibility of inadvertent disruption of the anterior lens capsule and subsequent cataract formation. The potential complication of hyphaema and cataract formation has been the primary deterrent to the widespread acceptance of Nd:YAG laser iridectomy as the preferential initial treatment for angle-closure glaucoma in phakic patients.

Laser contact lens

Anti-reflective-coated lenses so facilitate the procedure that their use is almost mandatory (Abraham, 1981). These lenses do the following.

1. Reduce extraneous eye movements that interfere with accurate superimposition of burns.
2. Assist in keeping the lids separated.
3. Focus the laser beam.
4. Minimize loss of laser power caused by reflection. Laser - tissue interactions
5. Gonioscopy solution absorbs excess heat delivered to the corneas, decreasing the incidence of corneal burns.

Abrahams lens consists of a fundus lens with a +66 diopter planoconvex lens button placed in its anterior surface. The button provides magnification without loss of depth of focus. The effective size of a 50 µm spot is reduced to approximately 30 µm, providing higher energy per unit area and permitting the procedure to be performed with a lower total energy. Posterior to the site of focus, the beam is more rapidly defocused, decreasing the potential injury to the posterior segment (Schirmer, 1983).

Wise lens is similar to Abraham's lens, but has a +103 diopter button, allowing even greater concentration of the laser energy (Wise *et al* 1986).

COMPLICATIONS

1. Blurred vision
2. Diplopia and glare
3. Corneal damage
4. Anterior uveitis
5. Posterior synechiae
6. Haemorrhage
7. Elevation of intraocular pressure
8. Lens opacities
9. Closure of iridectomy site
10. Retinal damage

Argon laser peripheral iridoplasty

Argon laser peripheral iridoplasty consists of placing a ring of contraction burns circumferentially on the peripheral iris in order to contract the iris stroma between the site of the burn and the angle, thus widening the angle itself.

Indications

1. Medically unbreakable attacks of angle-closure glaucoma
2. Plateau iris syndrome
3. Lens related angle closure glaucoma
4. Adjunct to laser trabeculoplasty
5. Nanopthalmos

Contraindications

1. Advanced corneal oedema or opacification
2. Flat anterior chamber

Technique

Pre-treatment measures

1. Performed on an outpatient basis under topical anaesthesia
2. Pilocarpine 2 % - 4 % is applied to stretch iris maximally

Laser parameters

1. Laser is set to produce contraction burns (500 µm spot size, 0.5 second duration, and 200-400 mW power).
2. Aiming beam directed to most peripheral iris via the contact lens (Abrahams lens).
3. Contraction effect is immediate and accompanied by noticeable deepening of the peripheral anterior chamber at the site of the burn.
4. Approximately 24 to 36 spots are placed over 360 degrees, leaving approximately 2 spot-diameter space between each spot.

Post-operative treatment

1. Topical steroid 4-6 times/day x 3 to 5 days.
2. IOP measurement and treatment if necessary.

Complications

1. Postoperative iritis is usually mild and responds to topical steroids.
2. Diffuse corneal endothelial burns: Usually disappear within several days and have not proved to be a major complication.
3. Elevation of intraocular pressure: Usually a transient rise occurs. If persists for a longer time, anti-glaucoma medication is required.

Laser treatment in open-angle glaucoma

Argon laser trabeculoplasty

Historical perspective

Krasnov (1973) attempted to create holes in the trabecular meshwork with the ruby laser to decrease outflow resistance. Consistent long-term efforts with argon laser treatment were not realized until Wise & Witter (1979) placed evenly spaced, non-penetrating argon laser burns around the entire circumference of the trabecular meshwork. The attention has also been directed to alternate methods of treating open-angle glaucoma with Nd:YAG laser (Goldstick & Weinreb, 1989).

Technique

The patient is seated at a slit-lamp. The eye to be treated is topically anaesthetized. A mirrored contact lens with methylcellulose is placed on the cornea. The initial treatment session consists of 180 or 360 degrees laser burns equally spaced at anterior half of trabecular meshwork approximately 40 to 50 laser spots (180 degrees) and 80-100 laser spots (360 degrees). The spot size is 50 µm with the spot duration of 0.1 seconds. The laser treatment is initiated at 800 mW. The power is either fixed or adjusted to achieve slight blanching or small-bubble formation. The intraocular pressure is monitored hourly for 3 hours and is reassessed after 1 week and after 4 to 6 weeks. The second half of the trabecular meshwork is treated as necessary. After the laser treatment, all preoperative glaucoma medications should be continued. Steroids are administered to reduce postoperative inflammation. Once intraocular pressure is stabilized, the physician may attempt to discontinue some anti-glaucoma medications.

Duration of effect of ALT

The optimal effect of ALT occurs within the first 4 to 6 weeks post-operatively. Several early studies demonstrated a stable intraocular pressure for 6 months to 1 year postoperatively (Lieberman *et al* 1983). Recently, however, the pressure-lowering effect of laser trabeculoplasty has been reported to decrease over time, leading to eventual surgical intervention. Schwartz *et al* (1985) followed 82 phakic eyes and demonstrated a 46 % success rate after 5 years.

Complications OF ALT

1. Elevated intraocular pressure
2. Progressive visual field defect
3. Peripheral anterior synechiae
4. Iritis
5. Hemorrhage
6. Corneal abrasion / oedema / endothelial burns
7. Pain

Contraindications

1. Uncooperative patient
2. Inadequate visualization
3. Hazy media
4. Complete angle closure
5. Corneal oedema

Relative contraindications

1. Uveitic glaucoma
2. Juvenile glaucoma
3. Less than 35 years old

Alternative laser treatments for open-angle glaucoma

1. Nd:YAG Laser angle treatment / trabeculopuncture

Limited clinical work has been done with Nd:YAG lasers (Epstein *et al* 1985). Gonioscopically, the surgical "holes" appear to close over several months and the pressure that was initially lowered return to pretreatment levels.

2. Nd: YAG laser trabeculotomy/sclerostomy

The capability of Nd: YAG laser to produce localized non-thermal damage and to influence non-pigmented tissue provides a theoretic advantage for performing a trabeculotomy or sclerostomy ab interno. Venkatesh (1986) has demonstrated in vitro that the Q switched Nd: YAG laser can create a penetrating opening through the trabecular meshwork into the Schlemm's canal using 30 mJ of energy, while causing minimal damage to adjacent tissue.

3. Nd: Yag laser goniotomy

Nd:YAG laser has been shown to be effective in lowering intraocular pressure in a limited number of patients with juvenile developmental glaucoma (Kitazawa *et al* 1985). By delivering the laser energy just anterior to the iris insertion, the iris tissue can be separated from the trabecular band.

Additional uses of laser therapy in glaucoma

1. Trans-pupillary argon laser cyclo-photo-coagulation

Ciliary body destruction is often considered the procedure of last resort in uncontrolled glaucoma. Direct photocoagulation of the ciliary processes offers precision in both knowing the exact number of processes being treated and in obtaining a direct effect on the target tissue. Treating via the pupil permits less disruption or destruction of intervening tissue. The procedure is especially useful for treating glaucoma in aphakia and neovascular, uveitic and malignant glaucomas uncontrolled by maximum medical therapy. At least 14 ciliary processes should be visible with maximum dilatation to make attempting the procedure worthwhile (Schultz, 1989).

Technique

Topical anaesthesia is required. The pupil is dilated widely. Goldmann three-mirror contact lens, a Lee goniolens or a Ricky cyclo lens can be applied to the cornea. The laser beam is focused on the tip of the ciliary process. The laser setting is adjusted to produce intense whitening with formation of a central crater at the tips of each process.

Complications

1. Hemorrhage
2. Mild iritis

2. Trans-scleral cyclo-photo-coagulation

The 1064 nm light of the Nd:YAG Laser penetrates intact sclera better than argon blue (488 nm), argon green (514nm) or Helium-neon (6733 nm) {(Fankhauser et al 1962)}. Clinical studies on human eyes have shown selective destruction of ciliary processes with promising results. Trans-scleral cyclo-photo-coagulation can also be done with the help of a Diode laser (810 nm). Diode laser is portable, small, compact, air cooled, requires minimal maintenance and is energy efficient. Diode laser is two times more efficient than Nd:YAG laser for trans-scleral cyclo-photo-coagulation.

Technique

Retrobulbar anaesthesia. Nd: YAG beam is retro-focused 3.6 mm posterior to the aiming beam. The aiming beam is then focussed at the level of the conjunctiva, 2 mm posterior to the limbus. A total of 32 to 40 evenly-spaced burns are applied over 360 degrees.

Complications

1. Conjunctival oedema
2. Intraocular inflammation
3. Hyphema
4. Corneal oedema
5. Hypotony
6. Vitreous hemorrhage

3. Reopening filtering fistulas

I. Trans-conjunctival treatment with argon laser

Failure of glaucoma filtration surgery usually results from external scarring (Fitzgerald & McCarthy, 1962). Pigmented tissue is usually present in the sub-conjunctival tissue at the site of the previously functioning bleb. The internal sclerostomy must be unobstructed for this procedure to be effective.

Technique

1. Topical anaesthesia
2. Abrahams iridectomy lens is positioned over the area of the bleb.
3. Careful focus on sub-conjunctival pigmented tissue.
4. Laser energy is increased until there is sub-conjunctival pigment disruption.
5. Successful treatment results in an immediate elevation of the bleb with lowered intraocular pressure.
6. Postoperatively, ocular massage is initiated and topical steroids are administered for 4 to 7 days.

II. Internal treatment of sclerostomy with the argon laser

Failure of filtration surgery can also result from blockage of the internal sclerostomy tissue (Addicks *et al* 1983). If this blockage is caused by pigmented tissue, it can be treated with the argon laser. This was first reported by Ticho and Ivry in 1977.

Technique

1. Topical anaesthesia
2. Goniolens placed on eye
3. Careful focus is obtained on the pigmented tissue inside the sclerostomy.
4. Power settings are adjusted to achieve vaporisation of the pigmented tissue.
5. When the procedure is successful, there is immediate lowering of the intraocular pressure associated with elevation of the filtering bleb.
6. Massage is initiated to encourage flow through the sclerostomy.
7. Topical steroid is administered for next 4 to 7 days.

III. Internal treatment of sclerostomy with Nd:YAG laser

Internal blockage is often related to non-pigmented tissue, which may be lens capsule, cortex, vitreous or fibrous tissue. The ability of the Nd:YAG laser to create photo-disruption, independent of tissue pigmentation, makes this an ideal laser for such treatment.

Technique

1. Topical anaesthesia.
2. Goldmann or Nd:YAG goniolens is placed on the eye.
3. Careful focusing at the level of the membrane blocking the internal sclerostomy.
4. Energy settings adjusted to obtain optical breakdown and tissue disruption.
5. Post-operative massage and topical steroids are started immediately and continued for 4 to 7 days.

4. Argon laser pupiloplasty

The size, shape and position of the pupil can be manipulated using light energy to create contraction burns of the iris tissue. The pupil can either by enlarged (photomydriasis) or pulled towards a better optical position (corneoplasty).

Glaucoma patients often have visual dysfunction secondary to miotic therapy. This can be especially pronounced if there is lens opacity. If pupillary dilatation results in an improvement in visual acuity or visual fields or both, the patient can be considered a candidate for argon laser photo-mydriasis. In a patient with a subluxated lens, the periphery of the lens may block the pupillary aperture, causing a significant reduction in vision. If the pupil can be moved beyond the periphery of the lens, then vision may be dramatically improved with an aphakic correction. Corneoplasty can be successful in these cases (Straatsma *et al* 1966). In patients with updrawn pupil, corneoplasty can pull the pupil down towards the visual axis. Finally, laser pupilloplasty can be successful in breaking attacks of acute angle-closure glaucoma associated with pupillary block.

Technique

1. Topical anaesthesia.
2. A contact lens is applied to the eye.
3. For photomydriasis, contraction burns are applied around the border of the pupil.
4. One row of 200 µm burns are placed circumferentially near the pupillary border.
5. One row of 500 µm burns is placed just peripheral to the first row.
6. Postoperatively, a short course of topical steroids for 7 to 10 days plus previous medical therapy.
7. For Argon Laser Corneoplasty, a local treatment of the iris is performed to either pull the pupillary border back to its original position or to pull it to a better optical position.
8. One row of contiguous 500um spots is placed just inside the collaratte border in the area to be pulled peripherally. A second row is placed just peripheral to the first row.

Complications

1. Transient plasmoid iritis
2. Moderate rise in intraocular pressure
3. Lens opacity
4. Progressive iris atrophy
5. Argon laser suture cutting

Elevated intraocular pressure after tratbeculectomy may be related to excessively light closure of the scleral flap. If the scleral flap was closed with a black nylon suture, then the argon laser can be used to lyse the suture through intact conjunctiva and release tension on the flap. Because sutures can easily be cut in a controlled fashion, scleral flaps can be closed more tightly, lessening the chance of early postoperative overfilteration. Treatment after 2 to 3 weeks may be ineffective, probably because of scarring of the scleral flap.

Technique

1. Topical anaesthesia and 2 % phenylephrine to blanch the superficial conjunctival vessels.
2. Hoskins contact lens is applied over the bleb site to flatten the tissue over the suture and blanch the deeper vessels.
3. After careful focussing, the suture is cut with a few laser spots.
4. Postoperatively, ocular massage is helpful to encourage flow.

Complications

Excessive filtration with resultant hypotony and a shallow anterior chamber have been reported, which usually respond to patching over 12 to 24 hours.

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