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3 Laser/Light Application in Ophthalmology: Control of Intraocular Pressure

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Abstract

The term "glaucoma" refers to a group of disorders that share common phenotypes. There are over 20 different subtypes of glaucoma. The glaucomas are defined by a characteristic loss of retinal ganglion cell axons leading to a progressive optic neuropathy that is related to intraocular pressure (IOP). If untreated, glaucoma can cause visual disability and even blindness. Although elevated intraocular pressure (IOP) is no longer formally part of the definition, it is recognized as the major risk factor for progression of the disease.

Keywords

Glaucoma · Intraocular pressure · Laser applications · Laser iridotomy · Laser iridoplasty · Laser trabeculoplasty · Cyclophotocoagulation

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- Glaucoma is a multifactorial optic neuropathy that results in progressive vision loss.
- The only treatable risk factor for glaucoma is intraocular pressure (IOP).
- Diagnosis of glaucoma requires measurement of IOP, assessment of vision loss by visual field testing, determination of corneal thickness, examination of the ocular fundus for signs of optic neuropathy such as cupping, and differentiation of open- and closed-angle glaucoma by gonioscopy.
- Treatment differs for closed-angle glaucoma (CAG) and open-angle glaucoma (OAG).
- Medications, laser procedures, minimally invasive glaucoma surgeries (MIGS) and incisional surgery are all critical to the management of glaucoma. The method of treating a particular patient depends on the severity as well as the type of glaucoma
- Laser iridotomy is the creation of a microscopic hole through the iris that serves as an alternate route of aqueous flow that bypasses the blockage at the pupil between the iris and the lens.
- Laser peripheral iridoplasty is a procedure that causes circumferential contraction of the iris away from the trabecular meshwork. Its main indication is CAG, specifically plateau iris syndrome, and is often attempted when

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laser iridotomy fails or is not indicated because the pathophysiology does not involve pupillary block.
- Laser trabeculoplasty is the application of laser to the trabecular meshwork with the intention of increasing aqueous outflow. Selective laser trabeculoplasty (SLT) is a technique that seems to be equally effective to argon laser trabeculoplasty (ALT). Advantages of SLT include a potential benefit from treatment following ALT, and theoretically its use for multiple treatments.
- Both ALT and SLT are effective first-line agents for primary open-angle glaucoma.
- Cyclophotocoagulation is the use of laser to destroy ciliary body tissue in order to decrease aqueous humor production and reduce intraocular pressure. Because of its higher rate of side effects and complications, it is usually reserved for glaucoma refractory to all other treatment options. There are four approaches to cyclophotocoagulation: contact transscleral, including transscleral cyclophotocoagulation and micropulse transscleral cyclophotocoagulation, noncontact transsceral, transpupillary, and endoscopic.
- There are a number of other applications for laser in glaucoma that are either adjuncts to or very similar to surgical procedures for glaucoma. These include laser sclerostomy, laser suture lysis, closure of cyclodialysis clefts, and goniophotocoagulation.

Introduction

- Glaucoma is a multifactorial optic neuropathy that is initially asymptomatic but can result in progressive visual field deficits.
- The prevalence of glaucoma increases with age, but can be seen at birth (i.e. congenital). Intraocular pressure (IOP) elevation is a major primary risk factor.
- The many types of glaucoma can be generally categorized into open-angle glaucoma (OAG) and closed-angle glaucoma (CAG).
- Diagnosis of glaucoma requires measurement of IOP and corneal thickness, optical coherence tomography of the retinal nerve fiber layer, ganglion cell analysis, assessment of vision loss by visual field testing, and examination of the ocular fundus for signs of optic neuropathy such as cupping, and differentiation of OAG and CAG by gonioscopy.
- The only clinically proven treatment for glaucoma is lowering the IOP. This can be accomplished with medications, laser surgery, and/or incisional surgery.
- Laser surgery has become increasingly popular as a treatment modality for glaucoma because the risks are favorable in comparison to incisional surgery. A number of lasers are used, the most common being argon, neodymium:yttrium-aluminum-garnet (Nd:YAG), and diode lasers. The specific laser used

Definition, Classification, and Epidemiology

The term “glaucoma” refers to a group of disorders that share common phenotypes. There are over 20 different subtypes of glaucoma. The glaucomas are defined by a characteristic loss of retinal ganglion cell axons leading to a progressive optic neuropathy that is related to intraocular pressure (IOP). If untreated, glaucoma can cause visual disability and even blindness. Although elevated intraocular pressure (IOP) is no longer formally part of the definition, it is recognized as the major risk factor, and only modifiable risk factor, for progression of the disease.

The subtypes of glaucoma are categorized into open-angle glaucoma (OAG) or closed-angle glaucoma (CAG). The “angle” refers to the iridocorneal (iris-cornea) junction at the periphery of the anterior chamber (Fig. 3.1). The angle is the site of drainage for aqueous humor. OAGs and CAGs are further subclassified into ‘primary,’ when the cause of the dysfunctional IOP is unknown, or ‘secondary,’ when the cause of the elevated IOP is the result of a known disease process. Furthermore, glaucomas are classified by their onset—acute or chronic. The most common

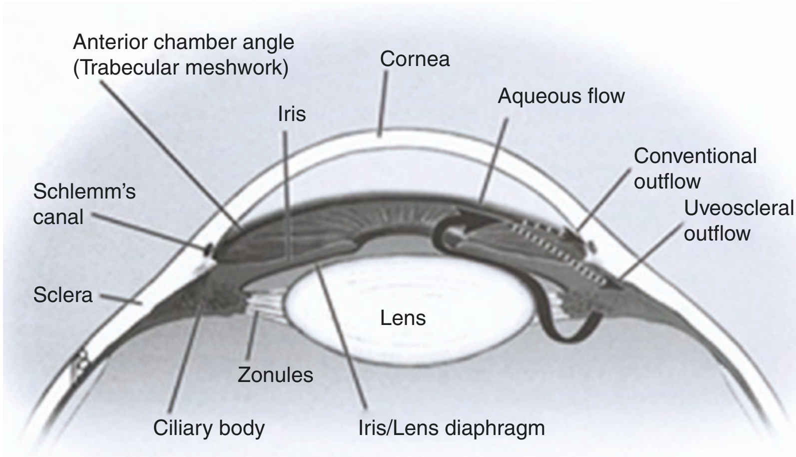

Fig. 3.1 Anterior segment anatomy and physiology

form of glaucoma in the United States is primary open-angle glaucoma (POAG).

With approximately three million Americans affected by glaucoma it is the second leading cause of blindness in the United States. Although it affects people of all ages, it is six times more common in those over 60 years of age than those 40 years of age. Annual medical costs for glaucoma services to glaucomatous patients and glaucoma suspects totals over 2.86 billion dollars.

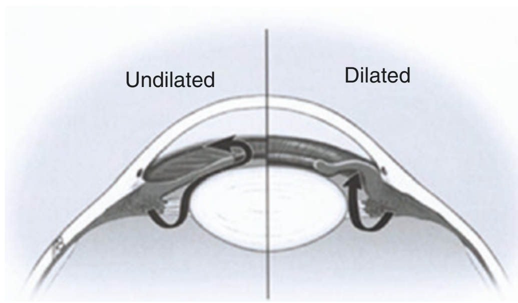

Fig. 3.2 Close-angle glaucoma due to pupillary block

Aqueous Physiology and Pathophysiology

Aqueous humor is a clear fluid that circulates in the anterior chamber of the eye to provide nutrients and remove metabolic waste from the avascular structures of the eye—namely the lens, cornea, and trabecular meshwork. The balance of aqueous secretion and drainage determines the IOP. Aqueous humor is produced by the ciliary processes, which are located behind the iris, through active secretion, ultrafiltration, and diffusion. Aqueous circulates within the posterior chamber, travels through the pupil, and exits the eye through the angle via one of two pathways (Fig. 3.1): (1) the conventional pathway through the trabecular meshwork, canal of Schlemm, intrascleral channels, and then episcleral and conjunctival veins; or (2) the uveoscleral pathway, through the ciliary body face, choroidal vasculature, and vortex or scleral veins. The conventional pathway is responsible for the majority of outflow, especially in older adults. CAG results from physical obstruction of these drainage tissues by approximation of the iris and cornea (Fig. 3.2). OAG occurs when aqueous drainage is impaired by increased resistance to aqueous drainage that is intrinsic to the outflow pathways (Fig. 3.3). Although it is possible that overproduction of aqueous humor could lead to an elevated IOP, all studies have shown that the pathophysiology is poor aqueous drainage. The average IOP is approximately 16 mmHg (2 mmHg standard deviation). An elevated IOP is defined as a value that is 2SD above the average (i.e., >20 mmHg). There is a form of OAG, named "low-" or "normal-tension glaucoma," in which damage occurs within the average range (11–21 mmHg). Although IOP reduction is often effective treatment for this type of glaucoma, other etiologic factors such as vasospasm or

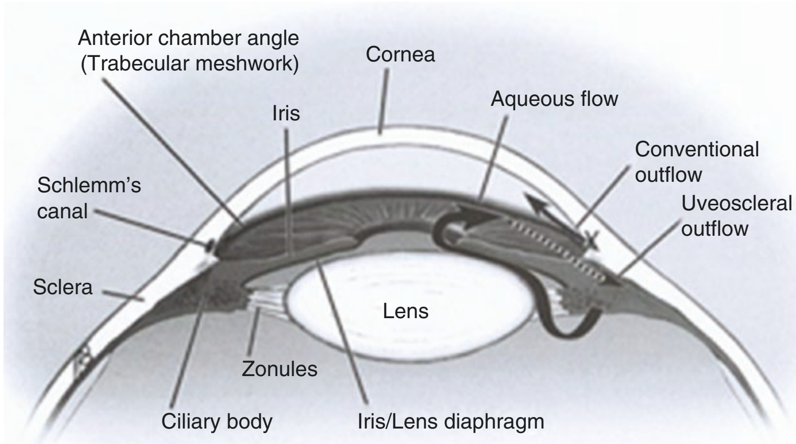

Fig. 3.3 Open-angle glaucoma

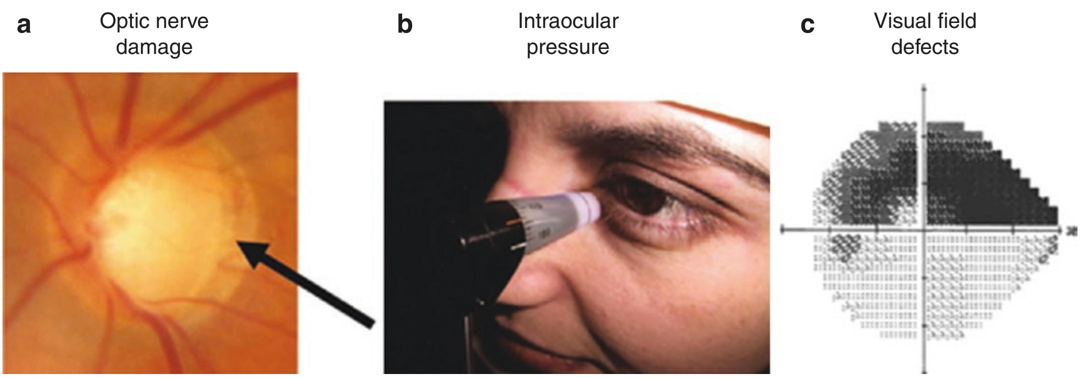

Fig. 3.4 Clinical triad of glaucoma, (**a**) optic nerve damage, (**b**) intraocular pressure, (**c**) visual field defects

ischemia are thought to have a larger role in the pathophysiology.

Symptoms

Vision loss from chronic glaucoma is usually painless and slowly progressive. Peripheral vision is usually affected first, and the deficits may be asymmetric. This results in delays in realization of vision loss.

Acute angle closure and a few secondary glaucomas present with symptoms, most commonly a painful red eye, blurred central vision, and rapid progression of visual loss. The presence of non-visually related symptoms are due to the rapid change in IOP causing immediate ischemic compromise of several ocular tissues—principally, the cornea and optic nerve.

Diagnosis

Diagnosis of glaucoma requires a complete history and ocular examination including measurement of IOP, determination of corneal thickness, assessment of the anterior chamber angle by gonioscopy, quantification of vision loss by visual field testing, and examination of the ocular fundus for signs of optic neuropathy such as cupping (Fig. 3.4). Gonioscopy is examination of the iridocorneal angle with a slit-lamp and contact lens containing mirrors to visualize the angle. Measurement of an elevated IOP identifies a significant risk-factor but is neither necessary nor sufficient for the diagnosis of glaucoma. Visual field defects and optic nerve defects characteristic of glaucoma are strong support for the diagnosis but other causes of optic neuropathy such as optic neuritis need to be excluded.

Treatment

To date, lowering IOP is the only clinically proven treatment for the glaucomas. Glaucoma suspects may also be treated depending on the presence of high risk characteristics and the individual risk aversion of the patient. The treatment approach differs between CAG and OAG. CAG treatment requires laser or incisional surgery to bypass the mechanical blockage. OAG can be treated with topical medications, laser, and/or incisional surgery. Topical medication may decrease aqueous production or increase aqueous drainage. Laser trabeculoplasty attempts to enhance the drainage function of the trabecular meshwork. Laser peripheral iridotomy creates a secondary pathway to allow aqueous to bypass a potential blockage; in doing so, equalization of the pressure gradient between the spaces anterior and posterior to the iris often allows the angle to deepen. Laser iridoplasty directly alters the angle anatomy by moving the iris away from the drainage structures. Glaucoma refractory to the above treatments may require cyclodestructive procedures to destroy the ciliary body and decrease aqueous production. Incisional operations such as trabeculectomy and glaucoma drainage implant devices create a new pathway to drain aqueous from the anterior chamber to the subconjunctival space.

General Comments Regarding Lasers in Glaucoma

Many lasers are used in glaucoma management. Their use has increased because their less invasive nature and generally lower rates of complications appeal to surgeons. The most commonly used lasers are argon diode and neodymium:yttrium-aluminum-garnet (Nd:YAG). The argon laser (488–514 nm) has a thermal effect on tissues, which either results in coagulation or vaporization depending upon the power settings used. The diode laser (810 nm) also has a photocoagulative effect. The Nd:YAG laser (1064 nm) has a coagulative effect when used in a continuous-wave mode. The short-pulsed q-switched Nd:YAG has a photodisruptive effect on tissues, which has an explosive effect. Other lasers have a photoablative effect that results in excision of tissue without any damage to the adjacent tissue. Photoablation has more applications for the cornea, but is also used in glaucoma. Besides the type of effect observed on tissues, different lasers may be used because they specifically target a certain type of tissue or because they have a desirable depth of penetration.

Laser Iridotomy

Iridotomy is the creation of a microscopic hole through the iris that provides an alternate route for aqueous to enter the anterior chamber (Fig. 3.5). Laser iridotomy is preferred over surgical iridotomy because it is safer, equally effective, and preferred by patients; however, surgical iridectomy serves as second-line treatment if laser iridotomy is unable to be performed (e.g. a patient who is unable to maintain position in the laser). The popularity of this established technological advancement is evidenced by utilization statistics. Although the total number of laser iridotomies and surgical iridectomies has increased in proportion to the aging population, the ratio of laser iridotomies to surgical iridectomies performed has increased from 15:1 in 1995 to 52:1 in 2004. The procedure is treatment for all forms of CAG that involve pupillary block. Patients with easily occludable angles may also require the procedure.

Indications and Contraindications

Indications

- Closed-angle glaucoma with pupillary block
- Narrow angles with signs of glaucoma
- Narrow angles with positive provocative tests

Contraindications

- Opacified cornea
- Uncooperative patient who is unable to maintain position for the procedure

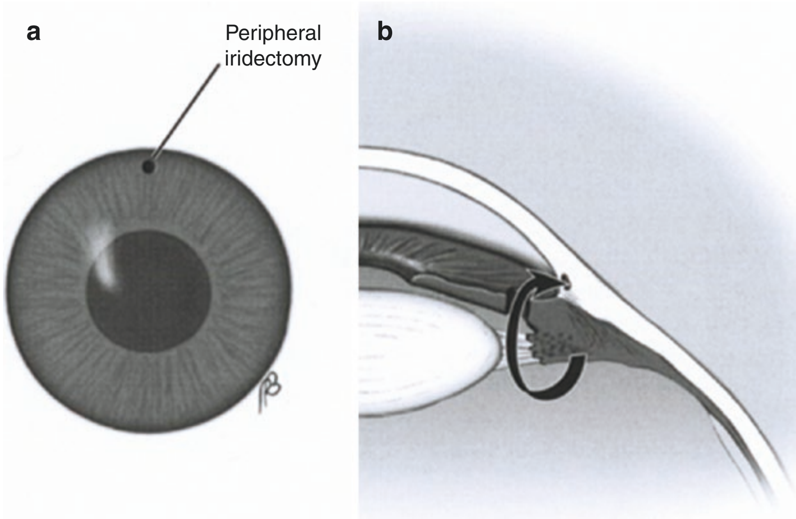

Fig. 3.5 Laser peripheral iridotomy, (**a**) shows clinical appearance of an iridotomy at the 12 o'clock position of the iris; (**b**) shows a secondary pathway to allow aqueous to bypass a potential blockage

The primary indication for laser iridotomy is to relieve pupillary block that may progress to acute angle closure glaucoma or CAG. Mechanistically, pupillary block is caused by an increased resistance to aqueous flow through the pupil because of anatomic obstruction of the pupil by the lens or another anterior or posterior structure. Increased resistance leads to a pressure differential between the anterior and posterior chambers, which results in anterior bowing of the peripheral iris over the trabecular meshwork. Laser iridotomy is indicated if pupillary block has caused angle-closure or is in imminent threat of causing angle-closure. Angle-closure glaucoma may be acute, intermittent, or chronic; and all are indications for laser iridotomy. If narrow angles are identified, then the risks and benefits of treatment should be considered. For example, treatment would be indicated if there are signs of previous attacks or if the fellow eye has CAG. Additionally, patients with narrow angles can undergo tests to provoke angle-closure such as administration of a mydriatic agent, exposure to dark, or placement in the prone position. These tests may cause IOP elevation, and therefore may serve as an indication for treatment. Finally, in eyes where the clinician feels the angle is potentially occludable, laser iridotomy is indicated.

Specific causes of pupillary block include phacomorphic glaucoma (glaucoma caused by an excessively large lens), a dislocated lens, anterior protrusion of the vitreous face, occlusion by an artificial (pseudophakic) lens in the anterior chamber, posterior synechiae (adhesions of the central iris to the lens usually as a result of inflammation), or extreme miosis. This is in contrast to CAG without pupillary block such as vascular or inflammatory diseases that may cause peripheral anterior synechiae (adhesions of the peripheral iris to the cornea). However, patients with CAG without pupillary block may also be treated with laser iridotomy because some degree of pupillary block may be secondarily involved. Nanophthalmic (small eye) eyes frequently develop CAG because they have very small eyes relative to the size of their natural crystalline lens. Pupillary block related to an enlarged lens may be a contributing factor in these cases. The same reasoning may extend to patients with primarily an OAG. If a pupillary block component is suspected, the benefits of eliminating such a factor may outweigh the risks.

Contraindications to laser iridotomy are few and primarily include findings that increase the risk of complications from the procedure. Corneal burns may result from either (1) use of laser through an opacified cornea, or (2) use of laser in an eye with an extremely narrow angle. There is also a risk of increased IOP following the laser procedure, and to avoid that, usually apraclonidine or brimonidine are instilled prior to the procedure, and the IOP is checked 30 min to 2 h following the procedure. Acute CAG with pupillary block is ultimately treated with laser iridotomy; however, the procedure should ideally be done following the acute phase after the eye's inflammation has had a chance to subside and the cornea has cleared. However, this is not always possible and laser iridotomy is still indicated if the cornea is clear enough to perform the procedure. Topical and systemic anti-glaucoma medications can acutely lower the pressure.

Techniques

- Topical anesthetic and miotic medications are applied preoperatively.
- The argon, diode, or Nd:YAG laser is used to apply laser to the peripheral iris through a focusing iridotomy lens.
- The photocoagulative effect of argon laser is dependent upon pigmentation; therefore, techniques vary for irises of different colors.
- The Nd:YAG laser is photodisruptive and therefore does not dependent upon tissue pigmentation.
- IOP-lowering medications are used perioperatively. Corticosteroids may be temporarily used postoperatively to control inflammation.

Pre-operative Management

Topical anesthetics are sufficient to provide anesthesia. A miotic agent is applied topically to thin the iris and pull it away from the angle. This allows for easier penetration and minimizes corneal endothelial injury. An Abraham iridotomy lens will help stabilize the eye, keep the eyelids open, provide a magnified view, and minimize corneal burns by acting as a heat sink and increasing the power density of the laser at the iris. The iridotomy site should be made in a relatively thin region of the iris, or in an iris crypt.

Description of the Technique

Q-switched Nd:YAG laser, the argon laser, and diode lasers can be effectively used for iridotomy. This review will focus on q-switched Nd:YAG and the argon laser because these two are most commonly used in practice. Each has unique properties that affect the selection of laser type and use of the laser for different colored irises. The q-switched Nd:YAG creates the iridotomy by photodisruption, an optical break-down of molecules into their component ions resulting in explosive disruption and essentially excision of tissue. One advantage of photodisruption is that it does not depend upon tissue absorptivity and therefore is equally effective for different colored irises. One disadvantage of photodisruption is its lack of coagulative effect. On the other hand, argon laser has a thermal effect and therefore results in photocoagulation or photovaporization, the specific effect depending upon the duration of exposure and energy density of the laser used. The thermal effect is beneficial in that it can provide coagulation. The disadvantage of argon laser is its dependence upon absorption by tissue pigments. Argon laser is ideal for medium brown irises, but may have a charring effect on dark brown irises and poor absorption in blue irises. As a result of the above differences, q-switched Nd:YAG laser is simpler to use, and argon laser iridotomy techniques vary for irises of different color. Specific descriptions of the techniques follow.

Q-switched Nd:YAG lasers have a wavelength of approximately 1064 nm and can be used at a range of power densities depending upon the number of bursts. Typically, there are 1–3 pulses per burst with each burst delivering 1–10 mJ. The focal point of the laser should be within the iris stroma to avoid corneal damage from the explosive effect. The iridotomy site should be at least 0.1 mm.

The effects of argon laser vary for tissues with different levels of pigmentation, therefore different techniques have been employed. The darker the iris color (i.e. greater amount of melanin in the stroma), the greater the absorption of the laser energy. Thus, the darker colored iris will require less energy to achieve the same results. Typical settings range between 600 and 1000 mW with a spot size of 50 μm with a duration of 0.02–0.05 s. The pit that is initially formed can be enlarged to a diameter of 0.2 mm with 30–70 pulses. Light blue irises have little pigment anteriorly (in the stroma) but the same iris pigment epithelium as brown irises posteriorly. As a result, the argon laser may penetrate the iris pigment epithelium but leave the stroma intact. A variety of creative techniques can be used to avoid this. One approach is to use longer exposures that generate heat that transmits to the stroma and creates a bubble. Laser entering through the apex of the bubble will repeatedly reflect within the bubble and more effectively ablate the stroma.

Although the first laser iridotomies were performed using the argon laser alone, in the modern era, either the Nd:YAG laser will be used alone or a combination an argon laser. Use of the two lasers minimizes the risk of hyphema and total energy delivered. Argon laser is used to for photocoagulation to increase tissue density and minimize the risk of bleeding. The Nd:YAG laser is then used for photodisruption.

Post-operative Management

Intraocular pressure is generally checked 30–120 min after the procedure. Apraclonidine or brimonidine are given perioperatively to mitigate elevations in pressure. Topical steroids may be given for several days post-operatively to control inflammation. If the angle remains narrow, laser peripheral iridoplasty may be considered, which will be described in the next section.

Adverse Events

Adverse events	Management
Iritis	Corticosteroids if more than mild
Increased intraocular pressure	Topical medications (α-adrenergic agonists, β-blockers, osmotic agents, or carbonic anhydrase inhibitors)
Cataract	No treatment
Hyphema	Pressure with contact lens for hemostasis
Corneal damage	No treatment
Failure to perforate	Retreatment after pigment cloud has dispersed
Late closure	Retreatment
Retinal burn	Avoid with standard precautions

Most side effects of laser iridotomy are often minimal and self-limited. *Iritis* occurs and is treated by post-operative corticosteroids or topical non-steroidal anti-inflammatory treatment. Persistent iritis may be related to a preexisting uveitis. *Intraocular pressure elevations* are common 1–2 h after the procedure but are usually self-limited and resolve within 24 h. Topical medications to lower IOP can be used to limit IOP elevation. Filtering surgery may be required if more severe and sustained elevations occur, more commonly in eyes with a component of OAG.

Most complications can be avoided with appropriate precautions and careful technique. *Cataract* may occur and is more easily formed by the q-switched Nd:YAG laser if it is applied to an open iridotomy site because the effect of the laser does not depend upon pigmentation. *Hyphema* is also much more common with q-switched Nd:YAG laser because it does not have a coagulative effect. Applying pressure with the contact lens usually provides sufficient homeostasis. *Corneal damage* may occur from either argon or Nd:YAG laser iridotomy. If the iridocorneal angle is closed or extremely narrow, the endothelium may be affected. No treatment is generally required, but if the iridotomy is incomplete, a new site may be selected. *Closure* of the iridotomy site may occur if the site is small or if there is an underlying uveitis.

Argon Laser Peripheral Iridoplasty

Argon laser peripheral iridoplasty is the delivery of thermal energy that causes circumferential contraction of the iris away from the trabecular meshwork. Laser iridoplasty is a treatment for certain closed-angle glaucomas, and is often attempted when laser iridotomy fails or is not indicated because the pathophysiology does not involve pupillary block.

Indications and Contraindications

Indications

- Closed-angle glaucoma without pupillary block (e.g. plateau iris syndrome)
- Preceding laser iridotomy for CAG with pupillary block and inflammation
- Preceding laser trabeculoplasty for focal areas of angle narrowing

Contraindications

- Severe corneal edema
- Peripheral anterior synechiae
- Corneal opacities—treatment through the opacity is not recommended

Closed-angle glaucoma without pupillary block is the major indication for laser peripheral iridoplasty. Plateau iris, an anatomic variant in which the posterior chamber structures are positioned more anteriorly resulting in an anteriorly displaced peripheral iris, is a configuration which can lead to closed-angle glaucoma without pupillary block (Fig. 3.6). Similarly, any posterior chamber or segment structure can cause the iris to be anteriorly displaced. This includes nanophthalmos, which results in a crowded anterior chamber, which predisposes patients to CAG.

Additionally, patients with closed or narrow angles that have laser iridotomy performed but continue to have narrow angles may be considered for laser iridoplasty. Laser peripheral iridoplasty may precede laser iridotomy in cases of acute CAG when the cornea is edematous and medications are not sufficient to control the attack. The effect of the iridoplasty lasts long enough for the corneal edema and anterior chamber inflammation to subside so that laser iridotomy can be performed under more optimal conditions.

Argon laser peripheral iridoplasty may also be used prior to laser trabeculoplasty in patients with open-angle glaucoma. It is indicated when patients have focal areas of angle narrowing, which can be opened to permit laser trabeculoplasty.

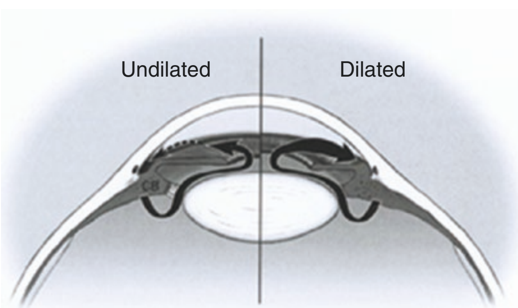

Fig. 3.6 Plateau iris

Contraindications include severe corneal edema and peripheral anterior synechiae. Laser peripheral iridoplasty will generally not open an angle that is scarred closed by peripheral anterior synechiae. Corneal opacities can also be contraindications; however, opacities that cover only a portion of the peripheral iris—such as pterygium—still allow for treatment of the remainder of the iris.

Techniques

- Topical anesthetic and miotic medications are applied preoperatively.
- Argon laser is used to create a photocoagulative effect to large areas of the peripheral iris circumferentially.
- Gonioscopy is used to ensure that the angle has deepened.
- IOP-lowering medications are used perioperatively. Corticosteroids are used postoperatively for inflammation.

Pre-operative Management

Topical anesthetic is sufficient to provide anesthesia. Pilocarpine is applied topically to constrict the pupil which will have the effect of thinning the iris tissue by virtue of spreading it over a larger area (i.e. place the iris under stretch). Apraclonidine or brimonidine is usually given before and after the procedure to reduce the risk of intraocular pressure elevations.

Description of the Technique

The argon laser is used for its coagulative effect to form contraction burns. The spot size is large (500 µm) with low power (200–400 mW) and long duration of delivery (0.5 s). The beam is aimed at the most peripheral iris to apply 20–24 spots are placed circumferentially, avoiding large radial vessels.

Post-operative Management

The peripheral anterior chamber should deepen immediately; therefore gonioscopy can be performed to confirm that the procedure was successful. Apraclonidine and topical steroid are given postoperatively to reduce the risk of intraocular pressure elevations and control inflammation. Topical anti-inflammatory treatment is continued for 3–5 days.

Adverse Events

- Side effects and complications are similar to those of laser iridotomy.
- Additionally, there is the risk of iris necrosis, which can be avoided with appropriate spacing of the laser spots.

Side Effects/Complications: Prevention and Treatment of Side Effects/Complications

Side effects include intraocular pressure elevations and inflammation. Their treatment is described above. Complications are similar to those of laser iridotomy. Additionally, *iris necrosis* may occur if the spots are placed too closely together. Spots should be spaced with 1–2 spot diameters apart.

Laser Trabeculoplasty

Laser trabeculoplasty is the application of laser to the trabecular meshwork with the intention of increasing aqueous outflow to reduce IOP in patients with OAG. It can be used as first line therapy, or after failed medical management. L laser trabeculoplasty can be offered as the initial treatment for patients with open-angle glaucoma as an alternative to medications in patients with early stage disease or in patients who are unable or prefer not to use topical medications.

The mechanism of increased aqueous outflow after laser trabeculoplasty is not well-understood. Three theories have been proposed to explain the efficacy of laser trabeculoplasty: mechanical, biologic, and cellular repopulation theories. The mechanical theory suggests that a thermal burn to the collagen results in local tissue contraction with mechanical stretch to the adjacent tissue. Presumably, the adjacent areas would have increased aqueous outflow. The biologic theory suggests that thermal energy stimulates trabecular endothelial cells to release matrix metalloproteinase enzymes, and recruits macrophages, which results in trabecular meshwork remodeling. The theory proposes that the resultant remodeling of extracellular matrix will increase aqueous outflow. The repopulation theory suggests that the laser energy stimulates trabecular endothelial cell division with downstream effects resulting in increased aqueous outflow.

The mechanisms above are potential explanations for the effect of laser trabeculoplasty performed with argon and diode lasers, techniques that were first proposed by Wise and Witter in 1979. Both of these types of lasers are equally effective in the long term (5 years); however, there are differing results in the short term (3 months), some suggesting a slight benefit to argon laser trabeculoplasty (ALT). ALT may also be technically easier since the end-point of laser application is more evident. A potential disadvantage of ALT is more post-laser pain and inflammation.

In 2001, a technique called selective laser trabeculoplasty (SLT) was approved by the Food and Drug Administration. SLT uses a non-coagulative double frequency Nd:YAG laser to selectively target pigmented trabecular meshwork cells without causing a coagulative effect. The absence of thermal burns suggests that the mechanical theory does not play a role in SLT.

More recently, a new technique called MicroPulse laser trabeculoplasty (MLT) has also come into use for OAG. This laser uses a 15% duty cycle rather than continuous laser wave (100% duty cycle). See "Future Directions" section for further discussion regarding MLT.

Laser trabeculoplasty has gained popularity in recent years. The number of laser trabeculoplasties performed decreased by 57% between 1995 and 2001 (perhaps as a result of the release of several new classes of topical antiglaucoma medications during this time), and then doubled from 2001 to 2004.

Indications and Contraindications

Indications

- Insufficient IOP control with medication
- Poor compliance with medical management
- Adult open-angle glaucomas (with the exclusion of uveitic glaucomas)

Contraindications

- Poor visualization of the trabecular meshwork (e.g. Angle closure, peripheral anterior synechiae)
- Hazy media
- Corneal edema
- Uveitic glaucoma
- Juvenile glaucoma
- Patients younger than 35 years unless their OAG is due to pigment dispersion syndrome

Relative Contraindications

- Patients with intraocular pressures >35 mmHg
- ALT should be withheld in patients with very narrow angles due to the risk of peripheral anterior synechiae; SLT may be used in these situations

The general approach to managing primary and secondary open angle glaucomas was previously to use topical anti-glaucoma medications, such as topical prostaglandin analogs, beta-adrenergic antagonists, carbonic anhydrase is treated initially, and if this fails to control IOP, the ophthalmologist may choose to treat the other 180°.

Smaller prospective randomized controlled studies have shown SLT is at least as effective as modern topical antiglaucoma medications. SLT may have a larger role than

ALT because mechanistically it does not cause as much tissue destruction. Hence, theoretically, SLT treatments can follow ALT treatments or SLT can be used exclusively for multiple treatments. The former has been investigated in a few studies, and results suggest that SLT is effective following both successful and failed ALT treatment. Typically, 180–360° of trabecular meshwork is treated.

Laser trabeculoplasty should not be performed if laser cannot be applied to the trabecular meshwork safely. This includes corneal edema or any corneal opacities, hazy aqueous, or angle closure including peripheral anterior synechiae. Uveitic glaucoma is also a contraindication, as the laser trabeculoplasty is ineffective and may aggravate an existing inflammatory state.

Techniques

Inhibitors, and selective alpha2-adrenergic agonists, as first-line treatments, and laser trabeculoplasty in patients that remain inadequately controlled. However, laser trabeculoplasty is now being used as first line therapy as an equally effective alternative to medical therapy due to its effective IOP lowering and repeatability. Incisional filtering surgical procedures are generally used when all other measures have not successfully controlled the eye pressure. Studies suggest that ALT has similar efficacy as first-line treatment compared with the medications available at that time. The Glaucoma Laser Trial was a randomized control trial that followed patients treated with medication or ALT for 7 years. The final IOP in the ALT group was 1.2 mmHg lower than the medically treated group, and their visual fields were slightly better concluding that ALT is at least as effective as medication as a first-line treatment. A study by Bovell which compared SLT to ALT found that SLT reduced IOP by over 6.5 mmHg at a 3 year follow-up, and that the efficacy of SLT was equivalent to ALT. A study done by Realini in patients from St. Lucia showed a mean 7.3–8.3 mmHg drop in IOP after patients were washed out from medical therapy. A Cochrane review concluded that laser trabeculoplasty controls IOP at 6 months and 2 years better than the medications used before the 1990s. Usually 180° of trabecular meshwork.

Pre-operative Management

Topical anesthetic is sufficient to provide anesthesia. Apraclonidine or brimonidine is usually given before the procedure to reduce the risk of intraocular pressure elevations.

Description of the Technique

A mirrored contact lens such as the Goldmann gonioscopy lens, Ritch lens, or Latina lens is used to stabilize the eye and visualize the angle at the slit lamp (Fig. 3.7). The laser beam is focused at the junction of the posterior trabecular pigment band and the anterior meshwork (Fig. 3.8). The specifics of the laser application depend on the type of laser being used.

- Topical anesthetic and miotic medications are applied preoperatively.
- Argon or diode laser is typically applied to 180° of the trabecular meshwork circumference with power settings adjusted to produce minimal blanching.
- Selective laser trabeculoplasty is typically applied to 180–360° of the trabecular meshwork circumference.
- Alpha agonists are used perioperatively. IOP should be rechecked perioperatively, and again after 1–3 weeks to determine the success of the procedure.

ALT and DLT generally require 40–50 spots over 180°. Power settings for ALT range from 400 to 1200 mW with adjustment to produce blanching and occasional gas bubble formation. DLT power settings similarly range from 570 to 850 mW but blanching is usually less noticeable. As a result, the surgeon must be more attentive with regards to which portions of the meshwork have been treated. The spot size with ALT is typically 50 µm with 0.1 s exposures. DLT spot sizes range from 75 to 100 µm with exposures ranging from 0.1 to 0.5 s. With both ALT and DLT, one should try to space the application spots by 1–2 application spot widths apart.

SLT requires a similar technique to ALT and DLT but the 532 nm frequency-doubled q-switched Nd:YAG laser is used with very different parameters. Seventy to 120 spots are applied over 360°. Laser may be applied to 90°, 180°, or 360° of the meshwork, with guidelines still in evolution; in general, it is recommended to treat 180–360° with most practitioners treating 360°. Only a small fraction of the energy applied in ALT is needed for SLT treatment. The duration of exposure is 3 ns. The power setting is on the same order of magnitude; however, because of the short duration of exposure the energy applied is 0.5–1.2 mJ versus approximately 100 mJ for ALT. Moreover, the difference in energy density is even greater because the spot size used for SLT treatments is 400 µm (0.5 mJ/µm^2 for ALT versus 10−5 mJ/µm^2 for SLT). The application spots should be spaced approximately 1–2 application spot widths apart.

Fig. 3.7 Patient position at slit lamp-mounted laser

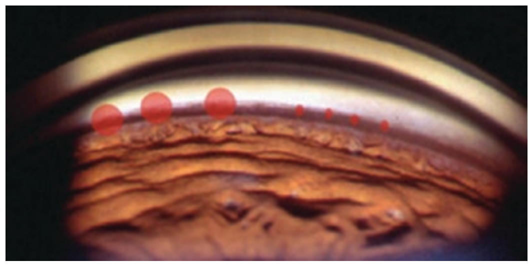

Fig. 3.8 Approximate sizes and locations of SLT (*left*) and ALT (*right*) laser spots

Post-operative Management

Glaucoma medications can be given postoperatively to reduce IOP elevations. IOP should be checked 30–120 min after the procedure and 1–2 weeks later. IOP reductions can be expected 4–6 weeks later, but can be seen as early as 2 weeks. If IOP reduction is inadequate, the remaining meshwork may be treated (for ALT and DLT or if only 180° of the meshwork were treated by SLT). There is no consensus on the treatment of post-operative inflammation following laser trabeculoplasty.

Adverse Events

- Transient and persistent IOP elevations may occur.
- Hyphema is rare and self-limited.
- Appropriate power settings and treatment locations will help avoid peripheral anterior synechiae.
- Mild iritis is common after ALT.

Side Effects/Complications: Prevention and Treatment of Side Effects/Complications

Transient as well as sustained *IOP elevations* may occur. *Hyphema* is rare and self-limited but can be treated by applying pressure to the globe with the goniolens or by photocoagulating with argon laser. *Peripheral anterior synechiae* are more common when areas posterior to the trabecular meshwork are treated. This should be avoided, and only the minimum power required to cause blanching should be used. Mild *iritis* is common after laser trabeculoplasty. Topical anti-inflammatories can control the inflammation, but is used judiciously as it can reduce the efficacy of the procedure. Laser trabeculoplasty is generally not helpful in patients with uveitic glaucoma and therefore should not be performed in most circumstances.

Cyclophotocoagulation

Cyclophotocoagulation is the use of laser energy to destroy ciliary body tissue usually in cases of refractory glaucoma. In contrast to all other procedures that have been described, the mechanism of IOP reduction for this procedure is a decrease in aqueous humor production, although some newer cyclophotocoagulation lasers may also increase outflow as well, which will be discussed later in the chapter. There are four approaches to cyclophotocoagulation: contact transscleral, noncontact transsceral, transpupillary, and endoscopic. Contact transscleral cyclophotocoagulation can be further separated into a traditional transscleral cyclophotocoagulation diode (TSCPC) and a micropulse translceral cyclophotocoagulation diode (MPCPC) Cyclodestructive procedures were traditionally used as a last resort for refractory glaucomas because of their relatively high rates of complications and side effects. However, with new advances, certain types of cyclophotocogulation procedures, such as MPCPC and endoscopic cyclophotocoagualation (ECP), are being used more commonly. These newer procedures have gained popularity over other cyclodestructive procedures such as cyclocryo-destruction because of its relatively lower rate of complications and side effects. The developmental trend with cyclophotocoagulation has been the use of lower power due to improved targeting; the lower power settings have improved the safety profile of these laser procedures.

Indications and Contraindications

Indications

- Refractory glaucomas
- Open-angle glaucoma in which other treatments are contraindicated (e.g. neovascular glaucoma)
- Glaucomatous patients with low visual potential or blind, painful eyes
- Poor candidates for incisional surgery

Relative Contraindications

- Glaucomatous patients with high visual potential, for transscleral cyclophotocoagulation

Traditional transscleral cyclophotocoagulation is usually for refractory glaucoma or glaucoma in which other treatments are contraindicated. Patients are already on maximal medication therapy with inadequate control. Filtering procedures have failed or may be high risk for the patient because of aphakic glaucoma, neovascular glaucoma, or perhaps glaucoma after penetrating keratoplasty. A less invasive procedure is also more appropriate for patients with low visual potential due to a decrease in post-operative procedures and visits. Cyclophotocoagulation can also be a procedure of choice for eyes that have very distorted anatomy or eyes with an opaque cornea. ECP was traditionally used for refractory glaucoma, however, is recently being used in less advanced glaucoma cases with cataract surgery, and can help to reduce eye-drop use. A study done by Roberts included 91 eyes in 73 patients who underwent ECP in combination with cataract extraction. The mean number of medications decreased from 1.88 ± 1.07 at baseline to 1.36 ± 1.18 at 1 month, 1.17 ± 1.14 at 3 months, 1.36 ± 1.19 at 6 months, and 1.48 ± 1.27 at 1 year. ECP allows for direct visualization of the ciliary processes allowing for the surgeon to titrate the amount of energy used. This leads to less complications, and compared to transscleral cyclophotocoagulation, ECP has less risks of hypotony, phthisis inflammation and can spare the conjunctiva and sclera in case of need for incisional glaucoma procedures.

Techniques

- Retrobulbar anesthesia is administered preoperatively if the procedure is done in the minor room. In an operating room setting, intravenous sedation can be used.
- Nd:YAG and diode lasers are the two most commonly used.
- The contact transsceral approach utilizes a fiber-optic probe to apply laser through the conjunctiva.
- The noncontact and transpupillary approaches utilize a slit lamp to apply the laser.
- Approximately 270° of the circumference of the ciliary processes are treated so as to reduce the risk of hypotony.
- Endoscopic delivery of laser for photoablation of the ciliary body is performed as an operative procedure due to the need to have an incision in the eye.
- MPCPC uses a hemispheric tip that is applied 1–2 mm posterior to the limbus, and is applied in a sweeping motion superiorly and inferiorly over 160–240 s

Pre-operative Management

Retrobulbar anesthesia is usually given for pain during and after the procedure. For the contact transscleral approach the eye is exposed with a speculum and the ocular surface is moistened with a saline solution before applying a fiber-optic probe to the conjunctiva. A slit lamp is used for noncontact transscleral and transpupillary approaches. Endoscopic cyclophotocoagulation is done in the operating room setting in patients who are already pseudophakic or in combination with a cataract extraction. MPCPC can be done in a minor procedure room with retrobulbar anesthesia or in an operating room with intravenous sedation, which is usually a less painful experience for the patient, and eliminates the need for patching the eye.

Description of the Technique

There is no standardized protocol for cyclophotocoagulation procedures, and studies report varying success and complication rates. The two most commonly used lasers are Nd:YAG and diode lasers. A prospective study comparing the lasers found no significant difference in visual acuity or IOP reduction between the two lasers; therefore, the diode laser is often preferred because of its portability and lower energy requirements to achieve the same tissue result. A retrospective review of recent data from transscleral cyclophotocoagulation procedures concluded that the diagnostic category and age of the patients influence outcome more than the specific laser protocol or total energy used. Usually, the circumference is treated while avoiding the 3 and 9 o'clock positions to avoid the long ciliary nerves. Treating more increases the risk of hypotony. Spot size is 100–400 µm with the 810 nm diode laser and 900 µm with the Nd:YAG laser. With the noncontact approach the laser is focused 3.6 mm beyond the surface of the globe; noncontact techniques are currently not favored. Pulse duration is 2–4 s at 1300–2300 mW with a total of 18–24 applications. The power setting is adjusted so that it is just below the power required to cause a barely audible 'pop.' The transpupillary approach may be used if the aqueous is clear and the pupil is sufficiently dilated so that ciliary epithelium can be directly visualized. Endoscopic cyclophotocoagulation is done through the anterior segment, or the pars plana. These procedures must be done in the operating room, and are often done in adjunct with cataract extraction. After a clear corneal incision is made, a high molecular weight viscoelastic should be inserted into the sulcus to lift the iris and facilitate visualization of the sulcus. An 18–23 gauge probe, 810 nm diode laser, 175-W xenon light source, helium-neon aiming beam, and video imaging are all within a fiber optic cable, which inserted into the anterior chamber via a clear corneal incision. The settings are between 250–350 mW, and 200–360° of the ciliary body are photocoagulated depending on the visualization of the angle. The ciliary processes can be visualized on a screen with an endpoint of photocoagulation leading to whitening and contraction of the processes without rupturing them. After the ECP procedure is completed, the viscoelastic should be aspirated from the eye. The approach for the MPCPC will be described in the "Future Directions" section.

Post-operative Management

Antibiotic and steroid ointments are given and the eye is patched overnight for transscleral cyclophotocoagulation due to the use of a retrobulbar block anesthesia. For ECP, patients may receive intracameral steroids or a subconjunctival injection of steroids in addition to topical drops after the procedure. Glaucoma medications are continued until IOP decreases, which may take several weeks. Retreatment may be necessary if IOP reduction is inadequate after weeks. It is not uncommon to require multiple treatments.

Adverse Events

- Pain is usually managed with systemic acetaminophen, ibuprofen, or cycloplegics depending on the source of the pain. Topical corticosteroid anti-inflammatory agents are also prescribed
- Hypotony, phthisis, hyphema, cataract, and synechia are significant risks

Side Effects/Complications: Prevention and Treatment of Side Effects/Complications

Common side effects include *pain, inflammation, postoperative IOP increases, iritis, reduced vision and macular edema*. Pain is usually managed with acetaminophen or ibuprofen. Pain secondary to iridocyclitis may be relieved with cycloplegics. *Hypotony* may develop after 6–36 months, and is one of the reasons that transscleral cyclodestructive procedures are a last resort. *Phthisis* is also a possible complication. However, these risks are lower with ECP compared with transscleral cyclophotocoagulation.

Miscellaneous Procedures

There are a number of other applications for laser in glaucoma that are either adjuncts to or very similar to surgical procedures for glaucoma.

Laser can be used to *cut subconjunctival sutures* placed in a number of different surgical procedures. The laser is preferred because the laser can cut the suture without having to incise the conjunctiva. Dark nylon or proline sutures that are too tight can be severed with argon laser. For example, trabeculectomy scleral flap sutures are usually placed tightly to avoid post-operative hypotony. To achieve the appropriate IOP reduction in the long-term, some of these sutures may be lysed with laser post-operatively.

Cyclodialysis clefts occur when ciliary muscle separates from the underlying sclera. This was once a treatment for glaucoma, but can also occur as a result of trauma or a complication of other surgeries. It results in hypotony and decreased vision. Use of the argon laser to deliver photocoagulative burns to the internal surface of the scleral in an attempt to scar these clefts closed has been described.

The iridocorneal angle may become vascularized eventually leading to neovascular glaucoma. This can result from a number of ischemic phenomena including diabetes mellitus and central retinal vein occlusion. Although panretinal photocoagulation is the primary treatment for these conditions because it is treating the source of the ischemic stimulus, *goniophotocoagulation* may be used as adjunctive treatment. Indications include anterior segment vascularization that is unresponsive to panretinal photocoagulation and cases in which angle vascularization is already present when panretinal photocoagulation is begun.

Laser sclerostomy is the use of laser to perforate the sclera at the iridocorneal angle has been investigated as an experimental treatment for glaucoma. Although not exactly the same, it can be thought of as the laser counterpart to a trabeculectomy, which is a guarded filtering surgery that is performed if glaucoma is not controlled with medication and laser trabeculoplasty. The laser can be applied externally with a goniolens or under a conjunctival flap, or internally. Numerous lasers have been studied and antifibrotic agents such as mitomycin C are sometimes used as adjunctive treatment; however, the role of laser sclerostomy in comparison to the well-known trabeculectomy surgery remains undetermined.

Future Directions

Laser-based procedures have been become much more common in all areas of glaucoma treatments. Their less invasive nature and lower rates of complications are appealing and seem to be motivation for research to refine existing procedures and for continued innovation in the field.

MicroPulse laser trabeculoplasty is a new technology. It uses a 15% duty cycle to deliver 300 µm pulses to the pigmented cells of the trabecular meshwork. The laser is believed to lead to release of inflammatory cytokines which increases the permeability of the trabecular meshwork and lead to decreases in IOP. The laser uses a longer wavelength of 532 or 577 nm in comparison to ALT, and is believed to cause less overall damage as it does not cause trabecular meshwork scarring like ALT, or destroy the pigmented trabecular meshwork cells like SLT does. Early, small scale studies have shown comparable IOP reduction between MLT and SLT.

Transscleral, transpupillary, and endoscopic-cyclophotocoagulation procedures have been described above. The micropulse transccleral cyclophotocoagulation diode is a newer method of transscleral cyclophotocoagulation. Its mechanism of action is not completely understood yet, but it appears to be multifactorial with belief that the diode causes ciliary body destruction, likely increases outflow through the uveoscleral pathway, and possibly causes a trabeculoplasty-like effect as well. MPCPC is believed to cause scleral shrinkage with ciliary body rotation and opening of the conventional outflow pathway. The diode is done transsclerally, but one of the differences between MSCPC and TSCPC is that micropulse diodes are delivered continuously with repeated times of short bursts of energy followed by rest. MPCPC has 0.5 ms in an active phase followed by 1 ms in a rest phase, with an overall duty cycle of 31.3%. The standard MPCPC settings are 2000 mW of 810 nm infrared diode laser on micropulse mode. The laser is then delivered over 360°, sparing the 3 o'clock and 9 o'clock positions, over 160–240 s. In contrast to TSCPC which uses a G probe, the MPCPC uses a G6 probe which has a hemispheric tip that protrudes 0.7 mm from the hand piece, and is held 1–2 mm posterior to the limbus during treatment. Given the duty cycle of the MPTCP, it is less inflammatory than the TSCPC. Although the procedure itself is painful, the post-operative pain is minimal. For this reason, the procedure can be done in a minor procedure room with a retrobulbar block, or in the operating room setting with intravenous sedation without a retrobulbar block. After the procedure, patients will be started on a topical steroid and atropine, and they should continue their current treatment for glaucoma. This procedure is repeatable if needed. Further studies must be done to understand the length of efficacy of the laser as well as the optimal patient.

Goniopuncture is the creation of a hole in the trabecular meshwork that results in a direct connection between the anterior chamber and Schlemm's canal and therefore, theoretically, increased aqueous outflow facility. The technique was initially proposed in 1950 by Harold G. Scheie but has been more intensively studied in the last 10 years as a treatment for open angle glaucoma. An erbium:YAG laser is used endoscopically often in combination with phacoemulsification cataract surgery. The erbium:YAG laser is a 2.94 μm wavelength laser that has a photoablative effect on ocular tissues with minimal thermal damage. One study found IOP reductions after 1 year similar to those after trabeculectomy. Another study found comparable IOP reductions at 1–3 years. Such a new procedure will require studies with longer follow-up and standardization of the technique and laser settings before it is fully incorporated into glaucoma management.

Conclusion

Glaucoma is a multifactorial optic neuropathy resulting in potentially progressive vision loss. Although there are many modalities of treatment that can be successfully employed to slow or stop the progression of glaucoma, the major and only treatable risk factor for glaucoma is elevated intraocular pressure. Diagnosis of glaucoma requires measurement of intraocular pressure, optical coherence tomography of the retinal nerve fiber layer, evaluation of visual fields, funduscopy, and differentiation of closed-angle glaucoma (CAG) and open-angle glaucoma (OAG) by gonioscopy. The management differs for CAG and OAG. CAG with a pupillary block component is treated by laser iridotomy. CAG without pupillary block may benefit from peripheral laser iridoplasty. Laser trabeculoplasty has been traditionally reserved for those requiring modest, IOP reduction; however, studies suggest that it is equally effective in lowering IOP as medications, and laser trabeculoplasty is a possible alternative as first line treatment for OAG If IOP remains inadequately controlled, filtration surgical procedures may be used. Cyclodestructive procedures such as cyclophotocoagulation have traditionally been reserved for refractory glaucoma because of their relatively higher rates of side effects and complications.

Iridotomy is the creation of an opening in the iris that provides an alternate route for aqueous to enter the anterior chamber bypassing the space in-between the iris and lens on its way to the pupil. The procedure is treatment for all forms of closed-angle glaucoma that involve pupillary block (i.e. increased resistance through or total occlusion of the space between the iris and lens). Patients with easily occludable anterior chamber angles may also require an iridotomy. Contraindications include an opacified cornea, an extremely narrow angle, or an inflamed eye. A topical anesthetic and miotic medications are applied preoperatively. The argon, diode, or Nd:YAG laser is used to apply laser to the superior peripheral iris through a focusing iridotomy lens. Absorption of argon laser energy causes photocoagulation and is dependent upon pigmentation and therefore techniques vary for irises of different colors. On the other hand, the Nd:YAG laser is photodisruptive and therefore does not dependent upon tissue pigmentation. IOP-lowering medications are used perioperatively, and corticosteroids may be used postoperatively for inflammation. If the angle remains narrow after treatment, laser peripheral iridoplasty may be considered.

Argon laser peripheral iridoplasty causes circumferential contraction of the iris away from the trabecular meshwork. It is another treatment for closed-angle glaucoma, and is often attempted when laser iridotomy fails or is not indicated because the pathophysiology does not involve pupillary block. This includes plateau iris and anterior displacement of the iris by posterior structures such as an enlarging lens. The procedure may be performed prior to laser trabeculoplasty to deepen focal areas of angle narrowing, and prior to laser iridotomy if the eye is acutely inflamed. Severe corneal edema or peripheral anterior synechiae are contraindications. A topical anesthetic and miotic medications are applied preoperatively. Argon laser is applied circumferentally to the peripheral iris to cause contraction burns. The effect should be immediately evident. IOP-lowering medications are used perioperatively, and corticosteroids may be used postoperatively for inflammation. Adverse events are similar to those of laser iridotomy with the addition of iris necrosis, which can be avoided by appropriately spacing laser spots. Laser trabeculoplasty is the application of laser energy to the trabecular meshwork with the intention of increasing aqueous outflow to reduce intraocular pressure in patients with open-angle glaucoma. The precise mechanism by which laser trabeculoplasty increases aqueous outflow is not fully elucidated. There is most support for a biologic mechanism involving enhanced turnover of extracellular matrix and induced trabecular meshwork cell division. Laser trabeculoplasty is now being used as first line treatment for OAG, and especially before filtering surgical procedures are performed for both primary and secondary open-angle glaucoma. Studies strongly suggest that both ALT and SLT are at least as effective as medications for initial treatment. MLT is a newer procedure which is believed to cause less scarring and destruction to the pigmented trabecular meshwork cells in comparison to ALT and SLT. Small scale studies have shown that it is equivalent to ALT and SLT in lowering IOP, however, larger scale studies are yet to be completed. Laser trabeculoplasty is not very effective in patients younger than 40 years and is contraindicated for uveitic glaucoma. It is also contraindicated if the angle cannot be appropriately visualized. The procedure requires topical anesthesia and IOP-reducing medications. Laser is applied to the trabecular meshwork using a mirrored contact lens. IOP reductions can be expected after 4–6 weeks. Complications include transient or persistent IOP elevations, hyphema, and iritis.

Cyclophotocoagulation is the use of laser to destroy ciliary body tissue in order to decrease aqueous humor production and therefore reduce intraocular pressure. Because of its higher rate of side effects and complications, it is usually reserved for refractory glaucoma. Cyclophotocoagulation has gained popularity over other cyclodestructive procedures such as cyclocryodestruction because of its relatively lower rate of complications and side effects. There are four approaches to cyclophotocoagulation: contact transscleral, noncontact transsceral, transpupillary, and endoscopic. Retrobulbar anesthesia is administered. Beyond general management the technique has not been standardized, and studies report varying success and complication rates. Most commonly, the Nd:YAG laser or diode laser is used to destroy most but not all of the ciliary processes so as to avoid hypotony. The contact transscleral approach utilizes a fiber-optic probe. MPCPC is a newer contact transscleral approach which is believed to work by causing ciliary body rotation and increase output through the uveoscleral and conventional pathways. In comparison to traditional TSCPC, it is less inflammatory and has fewer side effect. It causes less post-procedural pain in comparison to traditional TSCPC, and can be done in operating room with intravenous sedation, without a retrobulbar block. The noncontact transscleral and transpupillary approaches utilize a slit lamp to apply the laser. Glaucoma medications should be continued until IOP decreases, which may take several weeks. It is not uncommon to require multiple treatments.

Laser-based procedures have been become much more common in all areas of glaucoma treatments, in many cases replacing their surgical counterparts. Their less invasive nature and lower rates of complications are appealing and seem to be motivation for research to refine existing procedures and for continued innovation in the field.

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