Cyclodestruction

8

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History

Cyclodestructive procedures are the only glaucoma procedures designed to reduce aqueous production and are generally reserved for cases in which the outflow-enhancing procedures have either failed or cannot be safely performed. The first cyclodestructive procedure, sclerocyclotomy with thermocautery, was described in 1929 by Fiore [1]. In the following six decades, the approach varied among diathermy, cryotherapy, photocoagulation, and cyclocoagulation using ultrasound (Table 8.1) [1–19]. Most were associated with high incidences of hypotony, phthisis, scleral necrosis, and uveitis [3, 20]. The risks of these complications decreased over time, as improved technologies and protocols were developed.

In general, the goal of cyclodestructive procedures is to achieve targeted destruction/inactivation of the inner, nonpigmented ciliary epithelium on the ciliary processes, which decreases the overall aqueous production and lowers the intraocular pressure (IOP). Treatment precision can be achieved with identification of anatomic landmarks and utilizing a modality that delivers energy with tissue specificity [21, 22]. The diode laser (wavelength of 810 nm) is absorbed to a greater degree by the melanin in the ciliary process compared to the surrounding tissues, whereas direct, endoscopic visualization of the ciliary body provides a more precise identification of anatomy compared to transscleral techniques, which rely on external landmarks to infer the location of the ciliary body [23]. Thus, endoscopic application of diode laser allows for the most targeted treatment of the ciliary processes, although it requires incisional surgery, and therefore is, in a sense, the most invasive approach. Laser delivery is commonly achieved in a continuous fashion, which results in both apoptosis and necrosis. Recent introduction of micropulse delivery, with bursts lasting 30 to 300 microseconds interrupted by longer (1700–2000 microseconds) intervals, may result in tissue apoptosis with less necrosis compared to continuous pulse delivery [21].

Of all modalities of cyclodestruction, those of cyclocryotherapy, transscleral cyclophotocoagulation, and endoscopic cyclophotocoagulation have been reported in the pediatric population [14, 17, 24–26, 28, 29, 31, 32, 34],

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Table 8.1 History of human cyclodestructive techniques

Date	Medium	Techniques	Application	Population	References
1929	Electrode	Sclerocyclotomy with thermocautery	Ab externo, contact	Adult	Fiore [1]
1933	Electrode	Diathermy	Ab externo, contact	Adult	Weve [2]
1950	Dry ice	Cryotherapy	Ab externo, contact	Adult	Bietti [3]
1961	Polychromatic xenon light	Photocoagulation	Ab externo, contact	Adult	Weekers et al. [4]
1972	Pulsed ruby laser	Photocoagulation	Ab externo, contact	Adult	Beckman et al. [5]
1973	Nitrous oxide gas	Cryotherapy	Ab externo, contact	Adult	Bellows and Grant [6]
1973	Neodymium-doped glass laser	Photocoagulation	Ab externo, contact	Adult	Beckman and Sugar [7]
1981	Xenon arc	Photocoagulation	Ab interno	Adult	Charles [8]
1985	Ultrasound	Other coagulation	Ab externo, contact	Adult	Coleman et al. [9]
1986	Argon laser	Photocoagulation	Ab interno	Adult	Patel et al. [10]
1989	Nd/YAG laser	Photocoagulation	Ab externo, contact	Adult	Shields et al. [11]
1990	Nd/YAG laser	Photocoagulation	Ab externo, noncontact	Adult	Hampton et al. [12]
1990	Nitrous oxide gas	Cryotherapy	Ab externo contact	Pediatric	al-Faran et al. [13]
1991	Nd/YAG laser	Photocoagulation	Ab externo, contact	Pediatric	Phelan and Higginbotham [14]
1992	Diode laser	Photocoagulation	Ab externo, contact	Adult	Hennis and Stewart [15]
1992	Diode laser	Photocoagulation	Ab interno, endoscopic	Adult	Uram [16]
1997	Diode laser	Photocoagulation	Ab externo, contact	Pediatric	Bock et al. [17]
1999	Diode laser	Photocoagulation	Ab interno, endoscopic	Pediatric	Plager and Neely [18]
2010	Micropulse diode laser	Photocoagulation	Ab externo, contact	Adult	Tan et al. [19]

Nd:YAG neodymium-doped yttrium aluminum garnet crystal

with cyclocryotherapy now rarely used with the widespread availability of cyclophotocoagulation [27]. A limited series of nine pediatric patients treated with the external micropulse diode laser reported initial IOP lowering, but reoperation was required in seven (78%) patients during the first year of follow-up [35].The remainder of this chapter will focus on ab externo and ab interno, continuous pulse delivery of cyclophotocoagulation.

Indications

In eyes with uncontrolled glaucoma where additional incisional surgery is thought to be unfeasible or unsafe, transscleral cyclophotocoagulation (TSCPC) is considered. Usually, the risk of complications should be justified with the potential benefit of preserving vision, although the level of visual function may not be easily tested in younger children. TSCPC can also be considered following inadequately functioning glaucoma drainage device (GDD) surgery on maximum medical treatment. In pseudophakic or aphakic eyes with uncontrolled or borderline-controlled glaucoma scheduled for another intraocular surgery, such as vitrectomy and membranectomy to clear an opacified visual axis, endoscopic cyclophotocoagulation (ECP) can be performed concurrently for additional pressure control.

Contraindications

Cyclodestructive procedures have low success rate in eyes with uveitis [28]. In eyes with scleral thinning, TSCPC is relatively contraindicated for concerns of anterior scleral staphyloma formation and perforation [29]. It should be avoided in children with pigmentation of the sclera (e.g., nevus of Ota), which can preferentially absorb the energy and cause conjunctival and scleral burns. ECP is usually preferred over TSCPC in eyes with abnormal anatomy, where the position of the ciliary processes cannot be determined

accurately by external landmarks. Both TSCPC and ECP are usually performed under general anesthesia in a pediatric patient and would be contraindicated in children who are too ill for general anesthesia. The incidence of sympathetic ophthalmia (SO) in adults following TSCPC is estimated to be one in approximately 1500 [30], and pediatric cases have been reported [31, 32]. While it is not known if children are more susceptible to SO than adults, even a low risk of SO may be deemed unacceptable. Cyclodestruction is avoided in eyes with no light perception.

Risk Factors for Failure

Failure of cyclodestructive procedures is usually defined by inadequate IOP control, or sight-threatening complications, which may include chronic hypotony, cataract formation, post-laser inflammation, and choroidal and retinal detachment. Eyes with multiple prior incisional surgeries and/or prior cyclodestruction are at a higher risk of all complications [28–33].

Advantages and Disadvantages

The advantages and disadvantages of both TSCPC and ECP are outlined in Table 8.2.

Table 8.2 Advantages and disadvantages of cyclophotocoagulation techniques as compared to conventional glaucoma procedures

Advantages	Disadvantages
Short surgical time	Unpredictable response
Technically easy to perform	May require multiple treatment sessions
Prompt convalescence with fewer days of school missed	Ongoing medical treatment may be necessary
Fewer postoperative TSCPC precautions compared to incisional surgeries	Risk of sympathetic ophthalmia
ECP allows more targeted treatment	Increased risk of hypotony if subsequent incisional surgery were performed

TSCPC transscleral cyclophotocoagulation, *ECP* endoscopic cyclophotocoagulation

Preoperative Considerations and Preparation

When obtaining informed consent, it is useful to inform parents that in order to avoid hypotony and vision loss, treatment may be titrated over multiple sessions. This sets a reasonable expectation in case IOP is not sufficiently lowered after one session. Furthermore, parents must be advised that topical medical treatment may still be necessary after diode. The risks of postoperative vision loss from all causes and sympathetic ophthalmia are emphasized.

A list of instruments/devices is provided in Table 8.3.

Table 8.3 A list of instruments and devices needed to perform transscleral cyclophotocoagulation and endoscopic cyclophotocoagulation

Transscleral cyclophotocoagulation
Lid speculum
Semiconductor diode laser (Iris Medical Instruments, Mountain View, CA, USA)
G-probe (Iris Medical Instruments) or Ciliprobe (Katalyst Surgical, Chesterfield, MO, USA)
Fine-toothed forceps or squint hook
Transilluminator or ultrasound (for cases with difficult landmarks)
Optional IV ketorolac
Optional bupivacaine 0.25% (for subconjunctival injection)
Optional steroid (for subconjunctival injection, e.g., triamcinolone acetonide, betamethasone)
Prednisolone 1% (topical)
Atropine 1% (topical)
Endoscopic cyclophotocoagulation
Lid speculum
Microkeratome
Viscoelastic (for intraocular administration) or an AC maintainer
Mechanical vitrector (if pars plana approach and eye not fully vitrectomized)
Semiconductor diode laser (Endo Optiks, Little Silver, NJ, USA)
Endoscopic probe (Endo Optiks) – 20 or 23 gauge, straight or curved
Display monitor
Needle holder
Tying forceps
Fine-toothed forceps
Optional bupivacaine 0.25% (for subconjunctival injection)
Optional steroid (for subconjunctival injection, e.g., triamcinolone acetonide, betamethasone)
Prednisolone 1% (topical)
Atropine 1% (topical)

AC anterior chamber

Operation

Intraop Preparation General anesthesia is induced. A sterile preparation is not necessary for TSCPC, but mandatory and routine for ECP, whether or not it is combined with other intraocular procedures.

Surgical Technique For TSCPC, a speculum is introduced. A pair of fine-toothed forceps or squint hook can be used to stabilize and manipulate the eye. The footplate of the G-probe is applied to the limbus as specified by the manufacturer. However, transillumination to accurately identify the ciliary body is necessary in buphthalmic and anatomically abnormal eyes with the footplate adjusted as needed to treat the ciliary body. (Fig. 8.1) Initial settings are surgeon dependent. Consider 1100–1750 mW at 2-s duration (or 1250 mW at 4-s duration) for older children, while a power setting of 800–900 mW at 2-s duration may be appropriate for an infant. During the initial application, if a popping sound is heard (a marker of excessive tissue disruption), the power is adjusted downward at 50 mW or 100 msec increments until the sound is no longer heard or is barely audible. A reasonable initial treatment dose would be 18–30 laser spots dependent upon the energy levels over 270° (while avoiding areas of pre-existing glaucoma implants, scleral thinning, and long ciliary nerves at the 3- and 9-o'clock meridians). The treatment dose is titrated up or down based on the surgeon's experience, the preoperative IOP, and the patient's surgical history (Video 8.1).

ECP is essentially exclusively appropriate for aphakic or pseudophakic eyes, due to the difficulty reaching the target ciliary processes safely without injuring the native lens. After completion of the accompanying intraocular procedure, the pupils are pharmacologically dilated with intracameral administration of epinephrine. For pars plana approach, mechanical anterior vitrectomy is recommended to avoid traction on the vitreous base while performing the procedure. The endoscopic probe is made available, and the focus and orientation adjusted according to the manufacturer's instructions. The monitor is positioned within the surgeon's line of sight. The ciliary sulcus is inflated with viscoelastic or an anterior chamber (AC) maintainer is used. Under direct microscopic visualization, a 20- or 23-gauge endoscopic probe is introduced into the eye via a limbal (or pars plana) incision and advanced to the posterior chamber, with the tip of the probe positioned posterior to the contralateral iris border. The surgeon's attention is then turned to the monitor. The distance from the ciliary body is adjusted such that about four to five ciliary processes are visible on the screen at any given time. Too much distance will lead to insufficient photocoagulation, while too little distance will lead to excessive tissue disruption. With an initial power setting of 200 mW and continuous wave application, laser is applied to the ciliary processes until shrinkage and whitening occur without rupture of ciliary processes or bubble formation (Video 8.2). The power is adjusted up or down as needed for effective photocoagulation. A reasonable initial treatment dose would be one continuous coat of laser applied over 120–180°, titrated up or down based on the surgeon's experience, the target IOP, and the patient's surgical history. The viscoelastic is thoroughly irrigated from the eye, followed by meticulous closure of all incisions.

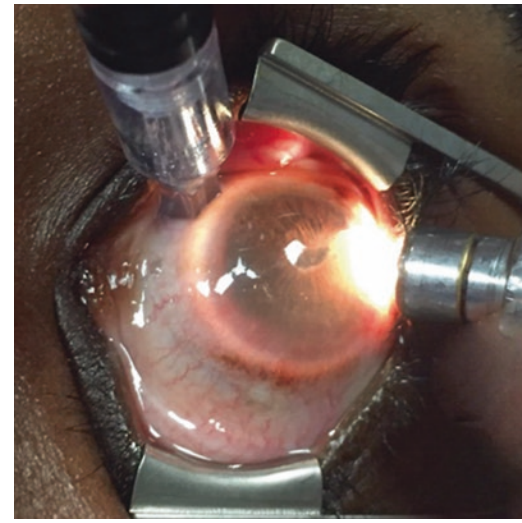

Fig. 8.1 Transillumination of a buphthalmic eye to identify the ciliary body. (Courtesy of Maria Papadopoulos, MBBS, FRCOphth)

Intraoperatively, various strategies can be employed to minimize postoperative inflammation with steroids given intravenously or via the sub-Tenon or intraocular route. Sub-Tenon or peribulbar bupivacaine injections are useful for control of postoperative pain. Acetaminophen as directed on the bottle for a few days generally provides adequate pain relief.

Potential Modifications As previously mentioned, when performing TSCPC in buphthalmic eyes or in eyes where the limbus cannot be clearly identified, transillumination with a Finnoff illuminator or comparable light source should be performed through the pupil. The junction of light and dark areas denotes the scleral spur and the anterior attachment of uvea. In ECP, a second incision can be created in order to access and apply laser to a larger extent of ciliary processes; in some cases, the irrigation and laser ports can be exchanged if placed at least several clock hours apart from one another. In microphthalmic eyes, consider using lower total energy and number of burns.

Postoperative Management

The patient is evaluated on the first postoperative day to rule out any immediate intraocular complications and/or acute IOP spikes and again approximately 5–7 days later. Topical atropine (once to twice daily) and prednisolone or dexamethasone (four to six times daily) are used for 2 weeks, followed by cessation of atropine and tapering of prednisolone. Preoperative glaucoma medications are resumed as needed depending on the target and outcome IOP or continued and withdrawn if possible. The patient is examined again in 3–4 weeks, after discontinuation of steroid medications. In uncooperative pediatric patients, echography is used to rule out posterior pole complications due to hypotony or inflammation, and a repeat examination under anesthesia is scheduled at the surgeon's discretion to obtain new baseline optic nerve and biometric examinations. Repeat laser application is usually delayed at least 8 weeks to allow for resolution of inflammation, discontinuation of postoperative topical steroid, and a more accurate assessment of the results of the initial procedure on the eye's IOP.

Complications

The risks of chronic hypotony (including phthisis), cataract formation, visual loss, and choroidal and retinal detachment may be decreased with judicious laser dosing, while the risk of severe postoperative inflammation may be minimized with intraoperative administration of systemic dexamethasone, intraocular or sub-Tenon steroid (e.g., triamcinolone), and postoperative topical steroids. In one series, the risk of chronic hypotony following TSCPC was 10% over an average of 30 months, with number of treatment spots being the only statistically significant difference (54 vs 41 spots in hypotonous vs no hypotonous groups) [30].

To avoid marked thinning of the sclera in TSCPC, attempt to apply the laser only in areas with sclera of reasonably normal thickness as shown by transillumination and consider other glaucoma procedures rather than only multiple TSCPC procedures.

The incidence of sympathetic ophthalmia (SO) in children following cyclophotocoagulation is unknown. A recent review of published diode cases estimated the incidence of SO to be around 1 in 1500 or 0.07% [30].

Outcomes

In refractory childhood glaucoma (primary or secondary), success rate is approximately 62–66% with one treatment, and 72–70% with multiple treatments, where success is defined as IOP < 21 mmHg or a reduction of 30% from pretreatment baseline [23, 24]. Approximately 10% of patients had decreased vision and/or significant postoperative inflammation, and 4–6% had choroidal or retinal detachment [23, 24].

In a retrospective comparative series comprised of most secondary childhood glaucomas, TSCPC and ECP had similar efficacy, and

approximately 46% of eyes were considered treatment successes, defined as IOP less than 21 mmHg at the most recent follow-up appointment, approximately 5 years following the procedure(s) [34]. Mean time to failure for TSCPC and ECP was approximately 1.7 and 1.0 years, respectively. In the subgroup who received TSCPC and ECP as initial glaucoma surgical therapy, 21% of TSCPC eyes and 45% of ECP eyes required subsequent incisional glaucoma surgery. Over 5 years, 23.4% (29/124) eyes lost vision, 5 eyes progressed to no light perception after complications from a corneal graft and retinal detachment, and 3 after GDD surgery [34].

Options After Failed Cyclophotocoagulation

The options after failed cyclophotocoagulation include:

- In eyes where additional incisional surgery is thought to be unfeasible or unsafe, repeat cyclophotocoagulation months to years later including any quadrant not previously treated.
- In eyes that have failed GDD surgery and diode, place a second GDD.
- In pseudophakic or aphakic eyes that have failed ECP combined with other surgery, consider GDD surgery.

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