TECHNIQUE REPORT

ADUNCTIVE LASER IRIDOPLASTY AND LASER GONIOPUNCTURE AFTER NON-PERFORATING TRABECULECTOMY

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Introduction

Successful non-perforating trabeculectomy (NPT) results in filtration of aqueous humor out of the anterior chamber and into a filtration bleb, without surgical excision of tissue from the anterior chamber angle, and without penetration into the anterior chamber. The complications of perforating trabeculectomy, due to early postoperative hypotony (shallow anterior chamber, hyphema, macular folds, suprachoroidal effusion, and ciliochoroidal hemorrhage) (3, 4, 5, 6, 7, 8, 9) are regarded by many surgeons as significant risks. Nonperforating surgery has been reported to reduce the incidence of early hypotony-related complications (10), because it has the advantage of creating gradual filtration of aqueous humor, through a thin trabeculodescemetic membrane (TDM), which markedly reduces postoperative complications seen after a conventional trabeculectomy (11), and also has been reported to provide better long-term intraocular pressure (IOP) control (12, 13).

NPT is reported to be a procedure with a significant learning curve, sometimes necessitating conversion to perforating trabeculectomy, and requiring careful postoperative monitoring (14, 15, 16, 17). Zimmerman *et al.* reported filtration of aqueous humor under a filtering bleb, by resecting the roof of Schlemm's canal and removing corneal stroma overlying the trabecular meshwork (18) Mermoud *et al.* reported filtration of aqueous humor under a filtering, bleb by unroofing Schlemm's canal and removing corneal stroma overlying the trabecular meshwork as well Descemet's membrane (19); he found that resistance across the TDM sometimes increased with time. When this resistance to aqueous humor outflow occurred, Mermoud found TDM resistance could be eliminated by performance of goniopuncture (*ab interno* Nd:YAG laser membranotomy via gonioprism), to enhance aqueous humor outflow into the filtration bleb.

Failure to filter adequately through the TDM is a potential complication following NPT which can result in a rise in intraocular pressure (IOP). In this paper we examine the effectiveness of adjunctive Nd:YAG laser goniopuncture (YGP) in patients who underwent NPT, to reduce post-operative IOP rise, secondary to scarring at or poor aqueous outflow through the TDM. Iris prolapse (IP) is another potential complication following NPT which can result in a rise in IOP. In this paper we examine the effectiveness of adjunctive argon laser peripheral iridoplasty (ALPI) in patients who underwent NPT, to reduce post-operative IOP rise, secondary to IP obstructing outflow across the TDM.

Background

Nd:YAG laser goniopuncture consists of placing several laser shots on the undersurface of the trabeculodescemetic membrane. The result is a microperforation in this membrane, with flow of aqueous into the filtration bleb, which converts a non-perforating filtration procedure into a partial thickness filtration procedure. In this technique, several high power, multi-burst shots are applied, *ab interno,* by a Nd:YAG laser via a gonioprism, to the underside of the TDM, to facilitate aqueous outflow out from the anterior chamber. YGP can be effective when increased aqueous outflow is desired postoperatively. After this procedure, patent perforation in the TDM is usually observed gonioscopically, generally accompanied with reduction in IOP, and increase in bleb elevation (in height and in circumferential extent).

Argon laser peripheral iridoplasty consists of placing several laser burns on the surface of the peripheral iris to contract the iris stroma, in a centripetal fashion, between the site of the burn and the anterior chamber angle. The result is iris stromal tissue contraction and compaction, movement of IP away from the angle and toward the pupil, which physically widens the angle and clears the synechial apposition of the peripheral iris against the TDM. In this technique, a series of low power, long duration, and large size burns is applied to the iris periphery to contract the iris stroma, to open the angle, and to clear IP causing synechial obstruction of the TDM after successful NPT. Used previously in acute angle closure glaucoma, ALPI may be effective in controlling IOP and clearing corneal edema when systemic and topical anti-glaucoma treatments fail to control high IOP, and when laser peripheral iridotomy (LPI) is not possible (e.g. in cases of severe corneal edema). Additionally, ALPI can be effective in permanently reopening the anterior chamber angle of iridectomized eyes with plateau iris syndrome; in this technique a full 360 degrees ring of spots is often applied, but a more limited area of treatment may also be effective.

Technique

When a post-operative elevation in IOP was detected in a patient's eye which had undergone NPT, careful indentation gonioscopy was performed to examine the TDM at the surgical site. If the

peripheral iris was flat, the anterior chamber angle was open, and the TDM did not appear obstructed by IP, YGP was performed. First, the eyes were pre-treated with aproclonodine 1% and pilocarpine 2% (if needed to allow visualization of the TDM). Next, a Nd:YAG laser was set on triple burst mode and shots were applied to the underside of the TDM at the NPT site, using a Goldman 3-mirror lens in the following manner: Energy – 3–5 mJ; Mode – Triple burst. The power and amount of spots were titrated in order to achieve partial or microperforation of TDM at the NPT surgical site, thus resulting in restoration of aqueous outflow into the filtration bleb.

When a post-operative elevation in IOP was detected in a patient's eye which had undergone NPT and or YGP, careful indentation gonioscopy was performed to examine the TDM at the surgical site. If irreducible synechial IP were detected, which obstructed filtration through the TDM at the NPT surgical site, ALPI was performed. First, the eyes were pre-treated with aproclonodine 1% and pilocarpine 2%. Next, an argon laser was set on blue-green mode and shots were applied to the IP adherent to cornea or to the TDM at the NPT site, using a Goldman 3-mirror lens in the following manner: Spot Size – 500 µM; Duration – 0.5 s; Power – 200 to 400 mW. The power and amount of burns were titrated in order to achieve partial or complete centripetal retraction of the IP from the TDM at the NPT surgical site, causing a clearance of the obstruction to the TDM, thus resulting in restoration of aqueous outflow into the filtration bleb.

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PURPOSE

To examine the effectiveness, using a retrospective, non-randomized, observational, consecutive case series, of Nd:YAG laser goniopuncture and argon laser iridoplasty to reduce post-operative intraocular pressure rise, in patients who had previously undergone non-perforating trabeculectomy to control IOP.

MATERIALS AND METHODS

A retrospective chart review was performed on 101 consecutive eyes of patients who underwent NPT from March 1998 to November 2002 from a single resident clinic (staffed by LFJ) and on 42 consecutive eyes of patients who underwent NPT from March 2000 to April 2004 by a single surgeon (LFJ) from a private practice office. Demographic data obtained from each patient included the glaucoma diagnosis, pre-operative and post-operative visual acuity, pre-operative and post-operative IOP, and pre-operative and post-operative number of glaucoma medications. Clinical data, including visual acuity, IOP, medications, and complications, were obtained at 1 day, 1 month, and last recorded visit following surgery. Patients who underwent combined glaucoma NPT and cataract procedures were also included in the analysis.

NPT procedures were performed using peribulbar anesthesia and supplemental intravenous sedation. After the conjunctiva was injected 7 mm behind the corneoscleral limbus and ballooned at 12:00 with 3 cc of topical epinephrine (1:1000) to aid in hemostasis, a microinvasive dissection was carried in the method reported by Ivanov . A circumferential, fish-mouthed conjunctival incision was made approximately 5 mm behind the conjunctival insertion from approx. 11:00 to 1:00, limbal-based dissection was carried down to bare scleral, and the limbal-based conjunctival flap was reflected onto the cornea. A 3x3 mm limbal-based half-thickness superficial scleral flap was demarcated by electrocautery, and was dissected into clear cornea. The superficial scleral flap was folded top-down toward the limbus, exposing the remaining half-thickness scleral bed.

A 3mm-limbal-based, triangular, deep scleral flap was demarcated by electrocautery in the bed below the superficial scleral flap, and was dissected into clear cornea until the limit of the conjuctival reflection. (This sizing facilitates conversion to a conventional guarded trabeculectomy in case of perforation into the anterior chamber when creating the deeper flap.) If dissection of the deep scleral flap exposed small areas of the choroid or ciliary body, the dissection was redirected to a more superficial plane without adverse effects. Using a mini-crescent blade, the deep scleral flap was carefully and meticulously dissected anteriorly, towards the conjunctival reflection and into the clear cornea. When the dissection was complete, a glass membrane could be observed overlying the iris stroma and the iris crypts, the scleral spur was exposed, and the cut-roof of the Canal of Schlemm was visible.

During the dissection of the deep scleral flap, it was important to identify the scleral spur, an important surgical landmark, lying immediately posterior to Schlemm's canal and identified by its circumferentially oriented fibers, distinct from those of the randomly oriented fibers of ordinary sclera. Failure of the dissection of the deep scleral flap to expose these circumferentially oriented fibers, before reaching clear cornea, indicated that the surgical plane of dissection was too shallow and required careful redirection. Once the deep scleral flap was created, it was hinged at the limbus, and folded toward the cornea; Schlemm's canal was exposed and was identified by its pigmentation, present in the posterior pigmented trabecular meshwork, and by its lumen, which was smooth, unlike that of the fibrous texture of sclera. From the floor of Schlemm's canal, a thin ribbon-like piece of tissue, representing the inner wall of Schlemm's canal, was resected posterolaterally with fine forceps, resulting in the removal of the floor of Schlemm's canal, exposing a visible gutter at mid-depth, and creating the trabeculodescemetic membrane, which consisted of tissue internal to both Schlemm's canal and the Desemet's membrane of the corneal.

At this point, a steady seepage of and pooling of aqueous humor was noted both at the site of the unroofed and unfloored Canal of Schlemm and as well, at the trabeculodescemetic membrane. In many cases, after exposing the TDM and removing the inner wall of Schlemm's canal, blood was seen refluxing at the cut ends of Schlemm's canal, indicating that the IOP (in a closed eye) had dropped under that of the episcleral venous pressure. When the ideal dissection, described above, was not attained in all patients, the inner wall of Schlemm's canal was scraped with a perpendicularly held blade until increased aqueous flow was seen in this area. The deep scleral flap was then retracted as far anteriorly as possible, and resected using fine microsurgical scissors. If this surgery was to be combined with cataract surgery, the superficial scleral flap and the conjunctiva were replaced in their anatomic positons, but not sutured, and phacoemulsification was performed by clear corneal incision at 10:00 and 2:00, using phacoflip with placement of a foldable posterior chamber intraocular lens in the capsular bag.

Since collagen device implants have been reported to improve surgical outcome in patients undergoing deep sclerectomy , for all patients in this consecutive series, a Staar AquaFlow implant was affixed at 12:00, using a single 10-0 nylon suture, in the bed of the deep scleral flap, along the altitude line of the limbal-based triangular excision. Since non-perforating procedures alone (*i.e.* without anti-metabolite) have been shown to provide only mediocre success in decreasing IOP, adjunctive 5-fluorouracil (5-FU), in a concentration of 1.5 mg in a volume of 0.03 ml, was administered intraoperatively (5 minutes for blue eyes, 7 minutes for hazel eyes, 9 minutes for brown eyes) using a 4x4 mm cellulose pledget placed at the NPT site's 12:00 position, between the superficial scleral flap (over the AquaFlow implant) and the bed of the deep scleral flap. The external superficial scleral flap was reapposed in its anatomic position, over the AquaFlow implant (but was not sutured) and the conjunctiva was lossely re-apposed, but not tightened with a running, non-locking, pursestring suture (of 8-0 polygalactin with a spatulated needle). At the appropriate time noted above, after removal of the 5-FU cellulose pledget, the residual 5-FU was irrigated subconjunctivally using Balanced Salt Solution, from the space between the superficial scleral flap and the deep scleral bed. The running conjunctival suture was tightened, the wound edges were closed, the suture was secured, and the conjunctival wound was checked for watertight-ness.

Postoperatively, the patients were maintained on topical fluoroquinolone antibiotics and prednisolone acetate ophthalmic medications, four times daily for 7 days. Thereafter, the antibiotic was stopped; the steroidal medication was continued twice to four times daily for at least 4 weeks and was tapered accordingly, depending on the level of anterior chamber inflammation, bleb height and extent, and the level of IOP. Routine postoperative exams were performed, at postoperative day one, week one, and month one (sooner and more frequently, if needed) where the anterior chamber, the filtration bleb, and the IOP were assessed. If and when needed, adjunctive YGP and ALIP were performed to reduce IOP.

Data compilation in those eyes requiring adjunctive YGP or ALPI included pre- and post-goniopuncture IOP and pre- and post-iridoplasty IOP. Statistical analysis was performed using two-tailed paired t-test.

RESULTS

Twenty-four eyes (24%) received adjunctive YGP from the 101 eyes which underwent NPT. Mean pre-goniopuncture IOP was 21.3 ± 5.8 mm Hg (range 12–32); mean post-goniopuncture IOP was 16.0 ± 7.8 mm Hg (range 6–38). This 25% mean reduction in IOP of 5.3 ± 7.2 mm Hg (95% CI: 2.2–8.3) was significant ($p < 0.02$). Fifteen eyes (36%) received adjunctive YGP from the 42 eyes which underwent NPT. Mean pre-goniopuncture IOP was 20.7 ± 8.1 mm Hg (range 8–42); mean post-goniopuncture IOP was 13.6 ± 6.3 mm Hg (range 5–26). This 34% mean reduction in IOP of 7.1 ± 6.3 mm Hg was significant ($p < 0.01$).

Sixteen eyes (16%) received adjunctive ALPI from the 101 eyes which underwent NPT. The mean time to iridoplasty after NPT was 97.4 ± 131.2 days (range 6–365); the median time to iridoplasty after NPT was 35.5 days. Mean pre-iridoplasty IOP was 23.1 ± 9.6 mm Hg (range 8–46); mean post-iridoplasty IOP was 14.9 ± 6.4 mm Hg (range 6–32). This 35% mean reduction in IOP of 8.2 ± 11.0 mm Hg (95% CI: 2.3–14.0) was significant ($p < 0.01$). Seventeen eyes (40%) received adjunctive ALPI from the 42 eyes which underwent NPT. Mean pre-iridoplasty IOP was 17.9 ± 6.1 mm Hg (range 3–32); mean post-iridoplasty IOP was 9.0 ± 5.9 mm Hg (range 1–22). This 50% mean reduction in IOP of 8.9 ± 5.9 mm Hg was significant ($p < 0.01$).

DISCUSSION

The principal advantage of non-perforating trabeculectomy over conventional, perforating trabeculectomy is, along with comparable IOP lowering effect, the reduction in complications usually seen in the early post-operative including: hypotony, shallow anterior chamber, choroidal detachments, lenticular-corneal touch. This is best seen when the eyes are allowed to re-equilibrate and readjust to the new lower IOP, the unfloored section of Schlemm's canal and the TDM are allowed to adjust to its new filtration responsibility, and procedures like ALPI and YGP are deferred for at least one month, if possible. NPT appears preferable to conventional trabeculectomy in patients prone to choroidal effusions: increased episcleral venous pressure, Sturge-Weber syndrome, or nanophthalmos. In contrast to trabeculectomy, extensive synechial angle closure in the area intended for the TDM is a relative contraindication to NPT, since filtration cannot reasonably be expected, unless the TDM is uncovered anterior to the synechiae. For this reason, to avoid such potential scarring, which could hinder surgical dissection and reduce the chances for a functioning TDM, the superior quadrant of the anterior chamber angle should be avoided when performing laser trabeculoplasty before possible NPT. While additional potential benefits of NPT include reduction in the risk of secondary cataract and reduction in the risk of early postoperative endophthalmitis, demonstration of these benefits was beyond the scope of this report.

The learning curve required for the dissection, needed to perform successful NPT, is not trivial. Even for experienced surgeons, it is difficult to perform the surgical dissection at a consistent depth during the creation of the deep scleral flap, to open Schlemm's canal and reliably scrape or strip its inner wall, and to uncover a 1 x 3 mm area of Descemet's membrane resulting in a clear and functioning TDM . While an ideal dissection probably prevents early postoperative IOP elevations, continuing prior glaucoma medications until good postoperative control is achieved may be a prudent course until confidence has been gained in the dissection required in this procedure. It must be noted, after NPT, filtration was obtained and IOP was reduced in some eyes when Descemet's membrane was uncovered, even though Schlemm's canal was not easily unroofed; conversely, after NPT, filtration was obtained and IOP was reduced in some eyes when Schlemm's canal was unroofed and its inner wall scraped, even though Descemet's membrane was not cleanly exposed as a glass membrane. Thus, important to the surgeon performing NPT, it appears that aqueous humor may be able to pass across or through, either the trabecular or Descemetic portion of the TDM. It would appear that scraping or stripping the inner wall of Schlemm's canal is an important part of this procedure, as this action removes not only the juxtatrabecular endothelial lining of Schlemm's canal, but also some juxtacanalicular tissue, thus reducing both trabecular as well as canalicular resistance. During the first postoperative month, on gonioscopic examination, several patients presented with blood visible in Schlemm's canal on either side of the TDM. Presumably, the blood had refluxed into Schlemm's canal, because both IOP and resultant pressure in the subconjunctival space were lower than the downstream episcleral venous pressure.

Failure to adequately filter through the TDM is a recognized complication which is especially consequential in non-perforating trabeculectomy. As subsequent fibrosis of the TDM can result in underfiltration of aqueous humor through the TDM, the NPT site should be examined with gonioscopy during the postoperative period. Worsening translucency of the previously clear TDM indicates possible synechiae between the superficial flap and the TDM and may indicate possible difficulty in performing successful YGP. It is possible that surgical implantation of a collagen space maintainer used in this technique would prolong the window of opportunity for successful YGP, but this is without the scope of this paper. Thus, despite uncomplicated dissection, resistance across the TDM can increase with time, resulting in increase in IOP. This can be treated by performing YGP, to create a microperforation in the intact but flow-resistant TDM, to enhance aqueous humor outflow into the filtration bleb, resulting in a reduction in IOP. Such underfiltration is in contrast to an overfiltration observed when microperforation results in a transient gush of aqueous humor during the dissection of the deep scleral flap, with neither iris prolapse nor anterior chamber shallowing; in such cases, no alteration of the procedure is needed and filtration through the TDM appears unimpaired. If a macroperforation results with release of aqueous humor and subsequent iris prolapse, the NPT can be converted to a standard trabeculectomy with good results.

Iris prolapse is especially consequential after NPT, when synechial occlusion of filtration through the TDM can result in an acute rise in IOP. IP appears to occur more frequently in eyes which undergo YGP in the first month after NPT, after that time conjunctival bleb scarring better resists overfiltration, reduces the risk of shallowing of the anterior chamber, resulting in a decreased chance for IP to occlude the TDM. Iatrogenic microperforation of the TDM during NPT is related to the learning curve of this surgery and ranges from a 30% to 50% for beginners to the procedure to less than 5% for surgeons experienced in the procedure. In some cases microperforation may be complicated by IP, which occurs when the trans-TDM flow of aqueous causes a centrifugal mechanical movement of the peripheral iris into the anterior chamber angle, resulting in a synechial adherence of the peripheral iris to or over the TDM. Argon laser iridoplasty works by causing centripetal shrinkage of the peripheral iris stroma, resulting in centripetal movement of the IP out of the angle, causing lysis of the peripheral synechiae, and clearance of the TDM to aqueous outflow and microfiltration. Indentation gonioscopy is an important and necessary post-operative tool after NPT, which allows for the early identification and treatment of IP. ALPI can increase the success rate for NPT either by allowing for increased uncomplicated (micro)filtration through the NPT site, or by allowing for increased likelihood of success for subsequent YGP of the TDM.

Using lifetable analysis, the greater than three-year success rate (defined as an optimally-low IOP without the use of drops) was over 89%. At the last follow-up visit, the mean number of medications taken by this group decreased from 2.9 Ī 0.9 (range 1 to 5) pre-NPT to 0.5 Ī0.9 (range 0 to 4) post-NPT ($P < 0.01$). Should scarring occur at the TDM, performing a Nd:YAG laser goniopuncture, causes a microperforation and reopens the TDM at the NPT site. Should excess filtration though the TDM result in iris prolapse and resultant synechial occlusion of the TDM, by performing an argon laser iridoplasty, the obstruction may be cleared and the IOP may be controlled.

Thus, with these adjuctive laser procedures after NPT, this filtration operation is comparable to or perhaps even better than a perforating trabeculectomy, relative to reduction in IOP and to decrease in meds, while virtually eliminating the risks of shallow chamber / hypotony, choroidal detachment / suprachoroidal hemorrhage, wound leak / bleb infection, and /or acceleration of a cataract.

CONCLUSION

Following non-perforating trabeculectomy, adjunctive Nd:YAG laser goniopuncture and adjunctive Argon laser iridoplasty appear to be technically simple procedures with minimal risk, which result in significantly lower IOP in patients with increased IOP secondary to inadequate filtration through the trabeculodescemetic membrane and which results in significantly lower IOP in patients with increased IOP secondary to iris prolapse and occlusion of the TDM. Further study is required to determine the long-term efficacy of these procedures.

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