Use of Nd:YAG Laser Capsulotomy
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Abstract. Surgery for cataract removal has become successively refined such that posterior capsular opacification is the most common problem presenting after modern cataract extraction. Various techniques and treatments exist to manage patients with posterior capsular opacification using Nd:YAG capsulotomy. There are many possible variations in initial assessment, pre-laser treatments, laser techniques, and follow-up routines. The literature on the use of Nd:YAG laser for capsulotomy was reviewed and interpreted. This article presents the currently available knowledge in a format that allows the practitioner to tailor an evidence-based protocol for treating patients with symptomatic posterior capsule opacification. (Surv Ophthalmol 48:594–612, 2003. © 2003 Elsevier Inc. All rights reserved.)

Key words. capsulotomy • laser • Nd:YAG • posterior capsule opacification

Published rates of posterior capsule opacification (PCO) vary widely, but a meta-analysis published in 1998 reported an overall rate of 25% of patients undergoing extracapsular cataract surgery developing visually significant PCO within 5 years of surgery.159 In the United States, Nd:YAG capsulotomy is estimated to cost the U.S. Medicare program $250 million per annum.177 The medical and significant economic implications57 of Nd:YAG capsulotomy requirements has led to an intense interest in reducing the level of PCO through research into the factors that affect its development. These include factors related to patients,11,42,94,96,129,167 surgery,145,146,152 or intraocular lens design and structure.44,105,134,135,193 Indeed, since the advent of modern small-incision phaco surgery with foldable lenses and sharper edge design, there is evidence to suggest lower values of PCO have been achieved.15,67,68,73,74,95,97,137,142,160,189

Opacification of the capsule is described most commonly in terms of lens epithelial cell growth that forms pearls or fibrosis.6 However, there are many other mechanisms through which the posterior capsule may be affected.124 Lens remnants may become trapped, imbibe water, and appear fluffy white. Mechanical distortion of the bag through folds or tears may cause irregularities in posterior capsule transparency. Proteins and white blood cells from posterior inflammation may deposit on the posterior capsule, as may red blood cells and pigmented cells from surgical trauma.124 Opacification of the posterior capsule can lead to clinically significant reduction in visual acuity, impaired contrast sensitivity, glare disability, and monocular diplopia.35,181

Treatment of Posterior Capsule Opacification With Nd:YAG Laser Capsulotomy

The problems caused by PCO can usually be remedied by laser surgery with Nd:YAG capsulotomy to
create an opening in the posterior lens capsule. However, this procedure is associated with complications such as damage to intraocular lenses, post-operative intraocular pressure (IOP) increases, cystoid macular edema (CME), disruption of the anterior vitreous face, and increased incidence of retinal detachment.

Before the development of Nd:YAG posterior capsulotomy, opacification of the posterior capsule was dealt with by surgical discission of the posterior capsule, either at the time of surgery or at a later date. Complications from this procedure were those that might be expected from such invasive surgery, and included endophthalmitis, intraocular lens dislocation, corneal endothelial cell loss, vitreous loss, and retinal detachment. In the early 1980s, the application of Nd:YAG laser as treatment for PCO was presented by Aron-Rosa and Fankhauser, at a time when the advantages of surgery with intact posterior capsules was becoming widely appreciated. Nd:YAG capsulotomy showed itself to be an effective alternative to surgical discission, avoiding such complications as endophthalmitis and vitreous loss.

Nd:YAG capsulotomy carries its own complications and risks, but most authors agree that these are reduced compared to surgical discission. Nd:YAG laser capsulotomy has since become standard treatment for PCO and gives rise to rapid improvements in visual acuity, relieving the symptoms of blur, photophobia, and glare.

During a posterior capsulotomy, the laser breaks the capsule by creating a pressure wave on the anterior vitreal side of the capsule. The pressure wave is a result of a process created by infrared light of 1,064 nanometers (nm) amplified and focused so that electrons are ripped away from nuclei, forming energy plasma and corresponding shock wave. This plasma formation is known as optical breakdown. Commonly used Nd:YAG lasers are either Q-switched, mode-locked, or both, which allows for greater efficiency, lower power settings, and fewer side effects.

Free radicals are produced during Nd:YAG laser capsulotomy, but these are unlikely to have any clinical effect. Over time, the capsular opening created tends to increase in size and becomes more circular, with smoothing of edge contour from capsular tag retraction. This is most evident if there is preoperative evidence of capsular traction or irregular capsulotomy borders post-discission. Mean increase in area in one study was found to be 32%. Using computer analysis of digital retro-illuminated images, Chao-Yu Hu et al found that capsulotomies enlarged progressively up to 1 month after Nd:YAG laser after which point they stabilized. Computerised analysis of retro-illumination digital images was used to make the measurements. At 3 months the area was 19% larger than at 30 minutes after capsulotomy.

The effect on pearls over time after a capsulotomy has been extensively studied by Caballero et al. Pearls are thought to be due to equatorial epithelial cells migrating across the surface of the posterior capsule and transforming into bladder cells, and more likely to have a large proportion of patients had some degree of pressure rise (25–90%).

Risks Associated With Nd:YAG Laser Capsulotomy

INTRAOCULAR PRESSURE RISE

Intraocular pressure rise after Nd:YAG capsulotomy has been well documented, and there are several postulated mechanisms. Obstruction of the trabecular meshwork by inflammatory cells and debris from the capsulotomy is thought to cause a reduced drainage capacity. Lynch et al showed a quantifiable reduction in outflow facility in monkey eyes following Nd:YAG capsulotomy, and histopathological studies after sacrifice of the monkeys showed the anterior chamber trabecular meshwork to contain fibrin, lens material, inflammatory cells, pigment, and erythrocytes. Studies using laser flare cell meter on human subjects also show that acute intraocular hypertension after capsulotomy is related to elevated aqueous particles. Schubert postulates specifically that the loss of dialyzable protein from disrupted vitreous is responsible for the IOP increase. Other postulated mechanisms include pupillary block due to the forward movement of vitreous and shockwave damage to the trabecular endothelial cells, release of inflammatory mediators, and direct effect on trabecular cells. Studies in the 1980s, soon after the inception of laser capsulotomy, were varied in their reported levels of IOP rise but tended to show that a large proportion of patients had some degree of pressure rise (25–90%).
The level of pressure rise was very variable among studies. For example, in a prospective trial of 526 patients, Keates et al found that IOP increased to 30 mm Hg or more in 5.7% and returned to pre-treatment level in 89% by 1 week post treatment.85 Stark et al showed out of a total patient population of 17,911 that 28% had an IOP increase of over 30 mm Hg from pre-treatment values.176 Many other studies from the early and mid 1980s show similarly high frequencies of significant IOP rise.33,121,154,155,169

Intraocular pressure begins rising in the period immediately after laser posterior capsulotomy.154,155 The pressure rise tends to maximize at 3 to 4 hours after laser treatment,21,155,169 and it returns to within 5 mm Hg of pre-laser values by 24 hours.21,155,169 Although the majority of authors found no long-term effect on IOP (in patients without pre-existing glaucoma), persistent IOP rise to 30 mm Hg lasting longer than 1 week was found in 0.8% of patients by Keates et al.85 In his study an average of 101 mJ was used in capsulotomies on 526 subjects of whom 448 were pseudophakes and 78 were aphakes. He states that the majority (84%) of the patients in whom IOP remained higher than preoperative level had not been medicated. He did not report any clinical evidence of damage as a result of the intraocular pressure rise such as visual field or optic nerve damage.

In a comprehensive FDA report, Stark et al found a persistent increase in intraocular pressure in about 1% of patients.176 In 1996, Jahn and Emke found in a case-controlled study that IOP rises permanently in many patients after Nd:YAG capsulotomy.77 This was in comparison to similar pseudophakic patients who had not been treated with laser. They stated that extracapsular cataract extraction alone mostly lowers IOP,28,64,65 and that many researchers may not have found significant long-term effects of capsulotomy on IOP as they were not comparing to opposite eyes or to controls who had cataract surgery. With a mean interval follow-up of 4 years for a capsulotomy group and 1.5 years for a control group of pseudophakes with no capsulotomy, they found that the ratio of pseudophakic IOP/ophosphate eye phakic IOP was higher in the laser-treated group than in the group with an intact posterior capsule (1.00 vs. 0.8, p < 0.0001). They conclude that most patients who have Nd:YAG laser capsulotomy will experience a relative permanent rise of IOP, to some degree, and actually advocated long-term follow-up of all patients. The argument that those patients that develop PCO might also be predisposed to developing increased IOP is not deemed feasible by the authors but perhaps warrants further consideration.

In a retrospective study by Fourman et al,53 involving 446 eyes, a late onset of increased IOP (mean follow up 2.7 years) was found in 5.9% of patients after laser, compared with 1.4% of general post-operative cataract patients without laser treatment. This suggests an incidence of IOP rise caused by Nd:YAG capsulotomy of around 4.5%. The increase in IOP in patients treated with laser in this study was 1 mm Hg on average. These patients had can-opener capsulotomies with “in the bag” implantation of IOls after extracapsular cataract extraction (ECCE) surgery. The authors point out that these were not eyes with persistently elevated IOPs, but rather patients who developed raised IOP 2 to 3 years later. There were no associated risk factors for this rise, and interestingly in the albeit limited period of follow-up (mean 3 years), there were no signs or symptoms of glaucomatous damage as a result of the pressure increases. The authors suggest the possibility that this laser-induced rise in IOP may be a form of ocular hypertension.

**Risk Factors**

The wide variation in results of the many studies may reflect the number of other independent factors that affect IOP after laser. Size of posterior capsulotomy created was investigated by Channell et al,33 who found that smaller capsulotomies lead to smaller IOP increases, with the suggestion that this is due to the smaller amount of debris released, and hence less trabecular meshwork obstruction. High total laser energy has been shown in some studies to be related to greater increases in IOP.33,155 Aron-Rosa8 reported that in 200 patients studied, all the pressure rises were when the energy per pulse was 2.5 mJ or higher. Type of intraocular lens (IOL) and surgical technique also may affect IOP rise, and it has been shown, for example, that eyes with capsular fixated bag IOLs have minimal IOP rises.9 Gimble et al58 report that bag-fixated IOls may provide more of a barrier to debris produced by the Nd:YAG laser than sulcus-fixated lenses, reducing blockage of trabecular meshwork. Further research is needed into the IOP rises with modern lasers, energy levels, surgery, and IOL types.

Patient-depandant risk factors include aphakia,79,154,155,169 glaucoma,149,155,166 pre-existing IOP of greater than 20 mm Hg,85 high myopia,166 and vitreoretinal disease.162,163 However, some studies have failed to show such associations with glaucoma56,76 or myopia.76 Slomovic et al failed to show correlation between IOP rise after Nd:YAG capsulotomy and previous history of glaucoma, presence of an IOL, or laser energy used.176

Some more recent studies show relatively low levels of IOP rise after Nd:YAG capsulotomy compared to earlier data. In 1994, Shani et al showed
only a 4% incidence of IOP rise of 10 mm Hg or more, when using can-opener anterior capsulotomy, and in 1997, Rakofsky et al showed a 7% rate of IOP rise greater than 10 mm Hg. Recent trends in cataract surgery may have had some effect in lowering the incidence and severity of these IOP spikes. Newer in-the-bag implantations of IOLs are more likely to form a tight barrier against dispersion of laser treated material into the trabecular meshwork. It may also be that more focussed and newer laser treatments tend to involve less dissipation of energy to the eye.

**Treatment**

Various treatments have proved useful in preventing or blunting the IOP spikes seen after Nd:YAG procedures.

**Apraclonidine**

Pollack et al used topical apraclonidine 1% and showed that elevations in IOP over 10 mm Hg reduced in frequency from 17% to 3% when used 1 hour preoperatively and postoperatively, respectively. Cullom et al studied the effect in glaucoma patients and found a significant effect in reducing elevations of IOP, when given once, immediately postoperatively. It is still possible, however, for patients treated with 1% apraclonidine preoperatively and postoperatively to develop marked elevation of IOP.

**Timolol**

Administration of 0.5% topical timolol has been shown to be effective in providing partial protection against IOP increase when given after Nd:YAG capsulotomy. Mean maximum IOP elevation was 8 ± 2 mm Hg following treatment with normal saline, 5 ± 3 mm Hg following treatment with 2% pilocarpine, and 1 ± 2 mm Hg following treatment with 0.5% timolol. Fewer patients treated with 0.5% timolol developed an IOP elevation over 5 mm Hg than control patients. Administration of drops was 5 and 30 minutes following Nd:YAG laser posterior capsulotomy. Migliori et al have shown, however, that pre-treatment alone with 0.5% timolol is not totally effective in preventing IOP rise.

**Levobunol**

A recent study showed an effective blunting of intraocular pressure rise, with a decrease of 7% to 0% in elevations over 10 mm Hg for both topical timolol 0.5% and topical levobunolol 0.5% when used 1 hour preoperatively and the same evening.

Earlier studies agree with these findings.

**Pilocarpine**

When used 5 and 30 minutes postoperatively, IOP elevations greater than 10% were reduced from 13% to 6% using topical 2% pilocarpine.

**Other Treatments**

Oral acetazolamide has been used for raised IOPs after Nd:YAG capsulotomy. Metipranolol has not been studied in detail in controlled trials and although use of topical steroids is mentioned in the literature, no controlled prospective trials have analyzed the isolated effect of topical steroids on IOP. Use of topical steroids have been recommended only for those patients with a history of uveitis or who have received a large amount of treatment energy.

Although the incidence of IOP rise is well documented along with evidence that administering doses of pressure-lowering drops reduces these IOP spikes, as yet there is no evidence that the temporary IOP rises actually cause damage to a patient’s long-term vision. There are no reports of vein occlusions, arterial occlusions, or optic nerve damage as a result of Nd:YAG capsulotomy unprotected by pressure-lowering drops. Hendrikse et al performed electroretinogram and electrooculogram recordings before and 3 hours after laser treatments. These were designed to be sensitive tests for retinal function and showed no difference before and after capsulotomy. Also, although initial field defects were found, these had disappeared by 3 hours. Unfortunately, IOPs were not detailed in the study. There are isolated reports of severe rises in IOP causing pain and visual loss but only until the IOP is brought back under control.

**RETINAL DETACHMENT/RUPTURE ANTERIOR HYALOID FACE**

Many studies on incidence of retinal detachment after Nd:YAG capsulotomy have shown increased rates (incidence of .5% to 3.6%) compared to patients who have not had laser treatment. It has been estimated that the risk is four times higher after laser capsulotomy. However, the low overall rates of detachment, variations in laser usage, and patient selection criteria, as well as many of the research papers published having methodological flaws, mean that a definite conclusion as to the true incidence of retinal detachment with modern surgery is not available. In 1993, Nielsen and Naeser, for example, report a rate of retinal detachment after Nd:YAG capsulotomy to be so low as to suggest no
causal relationship between Nd:YAG capsulotomy and retinal detachment.\textsuperscript{130}

However, most authors believe that the retinal detachment rate is increased after laser treatment,\textsuperscript{4,3,8,39,150,164,178} although the exact mechanism for the pathogenesis of this remains unclear. A physiological barrier between anterior and posterior compartments of the eye remains more intact after ECCE compared to intracapsular extraction.\textsuperscript{141,172} This barrier is known to be protective against retinal detachment as well as CME and anterior segment neovascularization.\textsuperscript{40,92,147} Smith et al used fluorophotometry to show that damage to the anterior vitreous during Nd:YAG capsulotomy is largely responsible for significant changes in the barrier effectiveness.\textsuperscript{173} More obvious clinically visible rupture of the anterior hyaloid face with displacement of vitreous into the anterior chamber has been reported in a high percentage of patients in early research.\textsuperscript{176,183}

Most authors believe that loss of intact posterior capsule initiates vitreous changes such as liquefaction.\textsuperscript{3,138,197} Indeed, animal studies have revealed a decrease in viscosity and depolymerization of the vitreous body after laser.\textsuperscript{99} Laser shockwaves may also directly induce vitreous change.\textsuperscript{99} Posterior vitreous detachments may then occur secondary to these vitreous changes. Posterior vitreous detachments are known to both cause new tears and allow existing tears to progress to retinal detachments.\textsuperscript{25,24} Ranta et al studied 220 eyes of patients due for Nd:YAG laser surgery and found no new breaks during capsulotomy, with only a very small percentage (one patient) developing a tear up to a month after laser.\textsuperscript{153} This suggests that asymptomatic breaks (potentially amenable to prophylactic treatment) might underlie retinal detachment in a higher than average number of patients with Nd:YAG laser.\textsuperscript{152} It may be that these asymptomatic breaks would not otherwise have lead to retinal detachment.\textsuperscript{25,39} In a retrospective study of 78 cases of pseudophakic retinal detachment, Sheu et al found that asymptomatic atrophic retinal holes might lead to retinal detachment preferentially after Nd:YAG capsulotomy.\textsuperscript{168} The authors advocate fundus examination and treatment of such holes after laser, as well as of other identified breaks. The states of the vitreous were not available in this study, and it remains to be shown whether a patient having already had a posterior vitreous detachment would still have an increased risk of retinal detachment after capsulotomy. One might expect that in a patient who has already had a posterior vitreous detachment further laser would not affect the risk of progression to retinal detachment as most theories on pathogenesis of laser induced detachments are based on vitreous damage. However, other possibilities do exist such as direct laser damage and transient acoustic shockwaves.\textsuperscript{190}

Some of the earlier studies that have suggested high rates of retinal detachment after laser, such as that of Javitt et al.,\textsuperscript{79} have been more recently qualified as less relevant to many modern pseudophakic patients, as they involved cataract extraction with posterior chamber IOLs not placed in-the-bag. As stated, in-the-bag placement is likely to lead to less barrier function loss in the event of Nd:YAG capsulotomy.

**Risk Factors**

Koch et al found that risk factors for retinal detachment include high myopia, lattice degeneration with associated holes, greater use of laser energy, and larger capsulotomy size.\textsuperscript{90} MacEwen et al studied 12 patients with post-capsulotomy detachments retrospectively and found that 11 of the patients had pre-existing risk factors for detachment: 3 had lattice degeneration, 3 had previous detachment, and 5 had axial myopia.\textsuperscript{112} Smith et al found that a posterior chamber IOL (PC-IOL) served to maintain an important mechanical barrier after Nd:YAG capsulotomy.\textsuperscript{173} They further postulate that adhesions between the PC-IOL and capsule remnants would induce further protection. Their protective effect would apply more to delayed capsulotomy procedures where the tighter bonds had time to develop.

**CYSTOID MACULAR EDEMA**

Cystoid macular edema is a common nonspecific inflammatory response of the macular area. It occurs after intraocular surgical procedures, trauma, and a variety of other inflammatory conditions affecting the retina.\textsuperscript{124} Although its exact pathogenesis is unknown, the final common pathway appears to be increased perifoveal capillary permeability, possibly associated with generalized intraocular vascular instability. Associated factors include inflammation with release of prostaglandins and vitreomacular traction. Surgical trauma causes the release of inflammatory mediators such as prostaglandins and leukotrienes. These substances may be responsible for the observed increase in parafoveal capillary permeability and serous leakage seen angiographically in CME.\textsuperscript{51} An increased rate of CME has been proposed to be associated with rupture of the anterior hyaloid face.\textsuperscript{38}

The etiology of CME following Nd:YAG capsulotomy most likely involves movement of the vitreous cavity and vitreous damage, which results in the release of inflammatory mediators.\textsuperscript{124} Vitreoretinal traction caused by the procedure may also play a part. Cystoid macular edema may be diagnosed by an unexplained loss of vision, or ophthalmoscopic
or angiographic appearance. Most cases of CME are mild and asymptomatic; the edema may only be apparent on fluorescein angiographic study (angiographic CME). More severe CME may produce symptoms of visual deficit (clinical CME). 183

Many studies have reported on the incidence of CME following laser capsulotomy, with most experimenters producing a figure of between 0.7% to 4.9%. 103,124 The wide variation probably reflects the differing patient samples, such as in terms of age or pre-existing ocular problems, differing follow-up times, and definitions of CME. For example, the criteria for diagnosing CME is not always explained in papers. 85 However, the majority of researchers agree with low rates for CME, mostly stating the rate to be below 1% and self-limiting in nature. 9,13,80,100,176,178 Lewis et al are critical of literature in this field for lack of adequate definitions of CME and reporting of detail of surgical procedures. 102 They present their own prospective trial of 80 patients who had fluorescein angiograms before and after laser. Masked independent observers reviewed the angiograms and defined CME according to pre-existing angiographic criteria described by Miyake. 125 No cases of CME were found after Nd:YAG capsulotomy in their study. Similar findings were reported from Bukelman et al, 22 who found no CME in a prospective trial of 68 patients. The actual rate of CME seems low when there is in-the-bag implantation and a period of time of some months between cataract surgery and laser. However, in the event of concurrent risk factors, such as complicated surgery, history of previous CME, and previous retinovascular disease, these risks can be more significant. 102

Lewis et al found a low rate of CME when capsulotomy was delayed for over 6 months from the initial IOL implant date. 102 A physiological barrier between the anterior and posterior compartments, comprising of anterior hyaloid, posterior capsule, zonules, and posterior chamber lens has been found to be protective against retinal detachments and CME. 40,92 Collateral damage to the anterior vitreous during Nd:YAG capsulotomy is blamed in one study for significant changes in the barrier effectiveness as measured by fluorophotometry. 175 The same study found that there was an additional protective effect of the mechanical barrier of the PC-IOL itself. 175 The PC-IOL may directly block the opening to the vitreous cavity directly limiting vitreous prolapse and damage. Adhesions between the PC-IOL and capsule remnants may provide additional protective effect. The fact that these adhesions would take some time to develop may explain the reduced rate of CME found with delayed capsulotomy. 92,102,178

Treatment

Effective therapy for CME is difficult to evaluate due to difficulties in quantifying the condition, the low incidence rates, and because of the high rate of spontaneous resolution. Treatments for pseudophakic CME may not necessarily apply to CME caused by Nd:YAG capsulotomy.

There are no randomized prospective trials showing definite objective response to treatments, but a common regimen involves initial prednisolone acetate 1% with a topical non-surgical anti-inflammatory drug (NSAID) each used 4 times a day for 4 weeks. Nonresponsive cases can treated with additional injected or oral steroids or oral NSAIDs. Although no additional details of treatment or results are defined, the author of this proposed regimen claims that under it most patients CME resolves in 3–12 weeks. 124

INTRAOCULAR LENS EFFECTS

Intraocular lens damage during Nd:YAG capsulotomy is well documented in the form of optic pitting or cracking. 176,192 Rates of damage have been quoted at between 4% to 40% of cases. Bath et al inspected damaged IOLs with scanning electron microscopy. 12 Each lens type had different patterns of damage, for example, lathe cut polymethylmethacralate (PMMA) lenses had stellate crater patterns where silicone lenses had a smooth splash-like pattern. The actual level of damage incurred seems to be dependent on various factors. Intraocular lens type affects amount of damage depending on both material and design. Various studies have shown some IOL materials to be more resilient to laser damage than others. Trinav et al determined the energy level required to induce a 50% incidence in IOL damage in various foldable IOLs compared to a PMMA lens (LX10BD; Alcon, Fort Worth, TX). 188 He found that silicone lenses were most easily damaged (threshold 0.37 mJ) followed by acrylic lenses (threshold 0.52–0.66 mJ). The PMMA lens was most resilient (threshold 0.68 mJ). The threshold values were defined as the laser energy levels causing damage on the IOL surface 50% of the time noticeable with a light microscope with ×375 magnification. The authors concede that the damage threshold of the lenses studied were all below the laser power normally set for capsulotomy, but still suggest that using the lowest possible energy helps to decrease the incidence of IOL damage. Bath et al determined the damage threshold in terms of power density (energy per spot area per unit pulse duration) for many commercially available IOLs available at the time (1985). 15 Power density applied for each mJ of energy is different from machine to machine, depending on pulse width and spot size of the laser machine. They recommended that only
power levels below the damage threshold be used in posterior capsulotomy to minimize lens damage. However, with the more modern IOLs the difference in threshold of laser energy required for capsulotomy and for lens pitting was negligible. Keates et al found that hydroxyethylmethacrylate and hydroxyethylmethacrylate polymers were less susceptible than lathe-cut PMMA lenses, which in turn were less susceptible than injection-molded PMMA lenses. Downing et al also found molded lenses to be more susceptible to damage than lathe-cut lenses. Injection-molded PMMA or silicone lenses seem to have greater susceptibility to damage than lathe-cut lenses.

Studies in this field have variations in laser systems used for capsulotomy. Also, in general, they fail to demonstrate significant margins from the energy required to penetrate capsule and the energy that damages modern IOLs. Although this means that studies fail to provide safe energy levels at which to do Nd:YAG capsulotomies, they do indicate which lenses may be at most risk and that using less energy minimizes the chance of damage.

Design of the IOL may affect level of damage by affecting distance between posterior surface of the IOL and posterior capsule. It has been shown that optical breakdown could occur up to 2 mm anterior to the laser focal point, depending on laser settings. Myers et al showed that convex-concave lenses afford protection by permitting a 2-mm separation between posterior capsule and IOL. Fallor et al showed that IOLs with a theoretical separation of 0.25 mm or more between lens and posterior capsule showed less damage in their study. There was no significant effect in this study of varying the laser type, with four different lasers being used.

Many early studies show an reduced rate of IOL pitting as the user gains experience. Thus relative user inexperience can be counted as a factor in IOL lens damage. However, given that lens strikes occur most frequently when the posterior capsule is in close apposition to the IOL, there may be no margin for error—the shock wave necessarily required to disrupt the capsule may also coincidentally be enough to cause IOL damage.

Downing et al studied damage to various PMMA lenses and found that by keeping energy output low and using converging contact lens to focus the laser energy just behind the capsule, damage could be kept to a minimum, and clinically insignificant.

Indeed, most studies that have reported lens damage state that no significant clinical effect on visual function is caused, even if the damage is directly within the visual axis. Keates et al in a study of 526 patients found some form of lens damage in 29.2% of lenses, but they found no instances of associated decreased visual acuity.

Although rare, if damage is severe enough to cause cracks in the IOL, then the effect may be enough to warrant explantation. Gardner et al, in a series of the first 100 patients treated at his unit, found two to have lens cracks, with significant effect on vision in one of those two. It seems that the damage threshold of IOLs decreases with exposure to multiple laser strikes. Although most lens strikes cause minimal visual loss, multiple lens strikes may cause problems of glare. According to Mamalis et al, extensive damage is infrequently seen, but extends beyond just the surface of the lens. This was stated to cause problems of blurring, distortion, or glare. They also present one case in which damage was severe enough to warrant explantation. Electron microscopy revealed severe laser damage in the forms of large cracks or fractures extending into the substance of the optic, as well as multiple areas of pitting.

IOL Movement

Using dual-beam partial coherence interferometry the procedure of Nd:YAG capsulotomy has been shown to induce a small but measurable backward movement of the IOL. No significant refractive change was reported. The movement was most pronounced in plate haptic IOLs. They propose that plate haptic IOLs tend to be compressed by capsule shrinkage and vault backward and propose this as the origin of the relatively higher rate of plate haptic subluxation post capsulotomy. Also they state that the larger capsulotomy openings induce greater backward movement, and recommend small openings to avoid this complication. There are several reports of displaced IOLs after laser treatment. Levy et al report two instances of hydrogel implant dislocation into vitreous following Nd:YAG capsulotomy, while the same phenomenon occurred with neither the silicone nor PMMA implants used in a similar time period. They postulate that the lens design is to maximize posterior capsule contact and that this has a tendency to redistribute any applied forces posteriorly against the capsule leading to posterior radial tears post capsulotomy, especially in oversized implants. Joo et al suggest that a smooth anterior circular capsulorrhexis generates more centripetal force to force the lens posteriorly. The newly created posterior opening is less smooth and not constricting and contributes to the posterior directed force on an IOL. Framme et al have presented two instances of IOL dislocation in standard PMMA lenses. The first was in a patient who had an existing posterior chamber tear, thought to have extended after laser treatment. In the
second patient the lens dislocated within an intact bag, with the zonulysis proposed to be caused by vitreous traction or capsule contraction post Nd:YAG. Other lenses reported as having dislocated include the Staar plate haptic silicone IOLs. Despite isolated reports of various types of IOLs found to dislocate, there are a greater number of reports documenting dislocation of plate haptic silicone lenses. Overall, however, reports are still rare and there are no studies of comparative incidence of dislocation of the various modern lenses after modern Nd:YAG. In one early analysis of 394 patients, Keates et al reported only one unspecified PC-IOL dislocating after capsulotomy.

Release of Toxins
There has been concern that the Nd:YAG pitting may release toxic by-products from the degradation of the PMMA polymer. However, it has been shown using various Nd:YAG pitted IOLs that no toxicity exists toward human endothelial cells or intact corneas. One study did show cytotoxicity but only to choroidal cells, at high laser settings and only with injection molded IOLs.

IRIS HEMORRHAGE
The Nd:YAG laser does not photocoagulate tissues when it cuts them so small vessels on the iris that are ruptured will bleed. If the bleeding does not stop immediately pressure from a fundus contact lens on the cornea usually helps stop the hemorrhage and there are no reports of this causing any significant long-term reduction of vision. Gardner et al found a 3% incidence if iris bleeding with resulting minimal hyphema which cleared completely by 1 week post laser. Overall, reports of early Nd:YAG usage (in the mid 1980s) suggest a rate of hemorrhage of around 1–5%.

CORNEAL EDEMA
Corneal edema has been reported when laser inadvertently strikes the cornea or from when IOP rise causes edema. There are no reports suggesting this is a significant problem in terms of permanent effect on vision.

UVEITIS/VITRITIS
In a study of 526 patients, Keates et al found iritis persisting in 0.4% and vitritis persisting in 0.7% after a 6-month postoperative period. Chambless, in a study with an average follow-up period of 7 months, found persistent anterior uveitis in 1.4%. Thus, although transient anterior chamber flare may be seen post-laser treatment, persistent iritis or vitritis is rare.

LENS REMNANT PROLIFERATION
Massive lens epithelial remnant proliferation has been reported, leading to significant visual loss following Nd:YAG capsulotomy. This was reported in eight cases with pre-existing retinal pathology (four proliferative diabetic retinopathy, one each of familial exudative retinopathy, retinopathy of prematurity, acute retinal necrosis, and fibrocellular epimacular membrane). It is postulated that the proliferation was caused by either the direct effect of laser on lens epithelial cells or by the disruption of the posterior capsule easing the passage of posterior segment proliferative agents to the capsular bag.

Lens capsule neovascularization can occur in pseudoexfoliative eyes that have undergone anterior segment surgery and Lotery et al suggested that such patients may also be at risk of massive lens cell proliferation after capsulotomy.

SECONDARY CLOSURE OF CAPSULOTOMY APERTURE
There are isolated case reports of proliferation of lens epithelial remnants after laser capsulotomy with clinically significant reduction of vision requiring further laser. A string of pearls may be seen to develop on the capsulotomy border, reducing vision. Oshika presented the case of total closure of capsulotomy by growth over posterior surface of lens, that required further laser capsulotomy.

McPherson et al found complete reopacification in 0.7% of 599 eyes studied. They found the risk to be higher in younger eyes (age less than 50 years) and suggest that the proliferating lens epithelial cells use the anterior hyaloid face or posterior surface of IOL as scaffolding.

More commonly, as discussed in detail above, pearls may spontaneously disappear some years after laser capsulotomy, perhaps by falling into vitreous, phagocytosis, or apoptosis.

Although not a commonly reported finding, Kumagai et al describe a significant incidence of anterior vitreous opacification in 1,101 eyes that they had treated with laser capsulotomy. Withing 1 month of treatment, 1.2% of patients showed anterior vitreous opacification. All had severe diabetic eye disease, with most treated successfully by vitrectomy. The researchers propose the cause of the vitreous opacification was due to the sequestering of lens epithelial cells in the vitreous.

OTHER COMPLICATIONS
There are single case reports of pupillary block glaucoma as well as aqueous misdirection syndrome. An energy total of 150 mJ was used in the latter case. Macular hole, retinal hemorrhage,
spreading of endcapsular low-grade endophthalmitis, and uveoscleritis are other complications that have been reported in isolation.

**BENEFITS OF Nd:YAG LASER CAPSULOTOMY**

In general ophthalmic practice, most attention is given to visual acuity when assessing a patient’s visual performance in relation to planned or executed procedures. The improvement in visual acuity after Nd:YAG capsulotomy in patients with significant PCO has been well documented. Aron-Rosa et al reported an immediate improvement in visual acuity in 94% of cases treated by capsulotomy. Terry et al showed improvement by one or more Snellen acuity lines in 92% of patients treated, and Slomovic et al had similar results. In a 1986 review by Weiblinger et al, overall visual acuity improved in 89% to 94% and decreased in 3.5% to 6%. In a more recent study in 1997, visual acuity measured with EDRS LogMar charts improved by a mean value of 11 letters post capsulotomy.

Improvements in glare and contrast sensitivity may be important outcome measures for many patients. Magno et al showed that as well as improvements in visual acuity, Nd:YAG laser capsulotomy also had beneficial effects on contrast sensitivity and glare disability as measured with brightness acuity tester (BAT). He and other authors found no association of pre-treatment visual acuity with pre-treatment glare sensitivity and suggested that documentation of both these values may be useful in management of patients being assessed for laser capsulotomy, especially if they complain of glare sensitivity but have good visual acuities. Sunderraj et al found that many patients who did not improve in visual acuity improved in glare tests after laser treatment. Wilkins et al report findings of laser capsulotomies improving not only vision but also glare and contrast sensitivity. He further suggested that if contrast sensitivity and glare are not shown to be affected in patients being considered for Nd:YAG capsulotomy then the clinician might be advised to look for other causes of reduced vision such as macular disease. Not all authors report glare sensitivity association with PCO, and variations in results are expected due to differences in glare testing methods as well as patient selection. Glare testing with a “straylightmeter” has been reported as more consistent than using the BAT tester. Despite variations in both method of assessment and spatial frequencies of tests. Although less consistent than contrast sensitivity, glare testing is still likely to yield additional information in evaluation of PCO. Further relevance of glare testing is given by studies on light scatter and glare testing on patients with large compared to small capsulotomies. Goble et al found, in only a small sample size of 12 patients that although Snellen acuity was equal in both groups, patients with larger capsulotomies (5–6 mm) benefited from improvements in glare disability and those with smaller capsulotomies (2–3 mm) did not.

Decision on whether a patient should proceed to capsulotomy or not is usually made based on a combination of the patient’s visual acuity and appearance of the patient’s posterior capsule, macula, and fundus visibility. Pearl-type opacification has a worse effect on visual acuity and contrast sensitivity than fibrous opacification. These factors are subjective and often deceptive making any accurate prediction of potential visual outcome difficult.

The two main methods proposed to overcome this problem are the potential acuity meter and the laser interferometer, both of which project an image onto the retina, attempting to bypass the PCO. The interferometer uses a laser to form an interference fringe directly upon the retina. These interference fringes are more resistant to degradation by refractive error and minor media opacity than is the normal retinal image, and they can be produced with an incandescent as well as a laser light source. The laser interferometer however has been shown in one study to have a significantly better correlation with visual outcome than white-light interferometers. The potential acuity meter projects letters onto the retina and the patient is asked to read the smallest line. The examiner scans the pupil with the beam of light to detect clear portions through which the patient may see smaller targets.

Many studies show a good level of correlation between visual outcome of laser treatment and potential acuity predicted by interferometer, with predicted vision to be within one line of actual vision in around 80–95% of patients. One study, however, did not document such a strong correlation, and visual acuity was predicted only to within one line in 38–56%. Smiddy et al showed potential acuity meter predictions to within one line in 73% of patients, with low numbers of false-positive and low false-negative predictions. Overall, results using the potential acuity meter were not as good as those using the interferometer. Klein et al show that one of the main problems of both potential acuity meter and interferometer is the high rate of false negatives, that is, that the prediction of poor visual outcome maybe erroneous. In addition, a study by Lue et al shows that a positive prediction by the potential acuity meter conveys more reliable information than a negative prediction. Poor pupillary dilation, dense media, as well as poor patient compliance and
communication have been proposed as causes for the high rate of false negatives.\textsuperscript{122}

Quantification of PCO may be performed by a variety of techniques including observation at slit-lamp, Scheimpflug photography,\textsuperscript{69} and computerized analysis of digital retroillumination photographs.\textsuperscript{60,185} A pilot study has shown that the latter may potentially help with assessment of PCO in terms of potential benefit from Nd:YAG laser capsulotomy (Aslam TM, presentation ESCRS Barcelona 2001). In this study PCO was quantified using computerized analysis of digital images taken with slit-lamp camera and analyzed with custom-designed software.\textsuperscript{185} Nd:YAG capsulotomy was performed and improvements in visual acuity and contrast sensitivity were found to correlate well with improvements in PCO analyzed.

**Deciding on Nd:YAG Capsulotomy Treatment**

The risks of Nd:YAG have been discussed in detail and may be minimized by tailoring the technique to suit the specific needs of the individual. The clinician must use the evidence available to decide whom to treat. Patient selection and precise tailoring of administration of capsulotomy in order to minimize risks and optimize benefit will now be discussed.

**PATIENT SELECTION**

As for any other surgical procedure the decision to proceed to Nd:YAG capsulotomy should be based on assessment of potential risks and benefits.

Benefits in terms of improvement in visual function of patients have been discussed above, with improvements in visual acuity, contrast sensitivity and glare widely reported following Nd:YAG capsulotomy. In addition to the patient’s visual benefit, the clinician is better able to examine the fundus. This has obvious advantages in management of conditions such as glaucoma, retinal tears and detachment, diabetes, and macular degeneration. However, another important consideration is the potential for Nd:YAG capsulotomy triggering deterioration in these comorbidities through inflammatory mediators released during the laser procedure. The potential for a negative impact on longer term control of these sight threatening co-morbidities merits further study.

**TIMING OF LASER**

Nishi and Nishi, in studies on rabbits, show that in explanted eyes 2, 3, and 4 weeks after PC-IOL implantation, lens capsule wraps tightly around the optic edge of the PC-IOL.\textsuperscript{136} Apple et al analyzed 5,416 pseudophakic postmortem eyes and states that a barrier effect is functional and maximal when the lens optic is fully in-the-bag with direct contact with the posterior capsule.\textsuperscript{4} Although Apple refers to a barrier against lens epithelial cells after cataract extraction, it has been found by Smith et al that a PC-IOL also serves to maintain an important mechanical barrier after Nd:YAG capsulotomy.\textsuperscript{173} They further postulate that adhesions between the PC-IOL and capsule remnants would induce protection.

In studies designed to look at the effect of square-edge optic designs on PCO development, Peng et al studied postmortem human IOL capsule interactions.\textsuperscript{146} Their photographs clearly show capsule adhesion to both to other areas of capsule and to IOL. Their protective effect may apply more to delayed capsulotomy procedures where the tighter bonds had time to develop. It has been noted that acrylic may enhance adhesion between the capsule and the IOL.\textsuperscript{20,126,145} In immunohistochemical studies on postmortem eyes these adhesions seem to be more prominent with acrylic material of Acrysof (Alcon, Fort Worth, TX) lenses than for PMMA or silicone lenses.\textsuperscript{106} Using Scheimpflug videophotography, however, Hayashi et al found the actual rate of capsule adhesion to IOL to be quicker in silicone IOLs than acrylic acrysof IOLs.\textsuperscript{66} In a recent study, of 70 patients after phacoemulsification surgery, he found complete apposition of the IOL to posterior capsule was on average observed in 7.4 days with silicone lenses and 11.1 days with the acrylic lenses.\textsuperscript{66}

These studies support claims that a delayed period of time between IOL implantation and Nd:YAG capsulotomy, in patients with in-the-bag implantation, might be protective against retinal tears, detachment, and CME. No controlled prospective trials have proven this or given an indication as to how much time is necessary.

As discussed above, there may in contrast be advantages in certain patients to early capsulotomy if PCO develops and requires treatment to enable proper visualization of developing posterior segment pathology.

**PREOPERATIVE VISION TESTS**

In general ophthalmic practice, most attention is given to visual acuity when assessing a patient’s visual performance in relation to planned or executed procedures. The improvement in visual acuity after Nd:YAG capsulotomy in patients with significant PCO has been well documented.\textsuperscript{32,55,191} Consideration should be given to the testing of other visual functions such as contrast sensitivity and glare, which also improve with Nd:YAG capsulotomy.\textsuperscript{195} In addition to being useful in the documentation of visual improvement, deficits in these functions may influence
decision to treat when visual acuity is relatively good as the functions are not necessarily directly associated with each other. Patients who do not have reduced visual acuity may improve, for example, in glare tests after laser treatment. Conversely, if visual acuity is reduced in a patient being considered for Nd:YAG capsulotomy and contrast sensitivity and glare are unaffected then the clinician might be advised to look for other causes of reduced vision such as macular disease.

The potential acuity meter and the laser interferometer have been reported to be of use if the clinician is unsure of potential benefit from Nd:YAG laser treatment. A positive prediction conveys more reliable information than a negative prediction. Aslam et al (ESCRS presentation, Barcelona 2002) have shown that computerized analysis of capsule remnants correlates well with eventual improvements in visual acuity.

PROPHYLACTIC TREATMENTS

Increased Intraocular Pressure

Rise in IOP is perhaps the most common of side effects of Nd:YAG laser capsulotomy. There is evidence, however, that this may have reduced in amplitude with the advent of newer techniques of surgery. Also, lower overall laser power seems to be used compared to when laser capsulotomy was first introduced, and this may contribute to fewer and less aggressive IOP rises.

Certainly if IOP spikes are a concern to the clinician, various treatments have been shown to produce effectively muted pressure rises, including 1% apraclonidine pre- and postoperatively, pilocarpine 5 and 30 minutes postoperatively, timolol 0.5%, and levobunolol 0.5% used 1 hour preoperatively and the same evening.

In assessing potential benefits of prophylactic treatments, the clinician should be aware that many reports have shown a significant proportion of patients with very marked temporary pressure rises but also that despite this, there are very few reports of any functional permanent visual deficit as a result of these pressure rises. The eye drops given to prevent IOP problems have in contrast been known to cause significant, sometimes severe side effects in some general patients on treatment.

The clinician may be more liable to treat patients for IOP prophylactically if risk factors for development of significant IOP rise are present. Patient-dependant risk factors include aphakia, glaucoma, pre-existing IOP of greater than 20 mm Hg, high myopia, and vitreoretinal disease, although other studies have failed to show such associations. Slomovic et al. for example, failed to show correlation between IOP rise after Nd:YAG and previous history of glaucoma, presence of an IOL, or laser energy used.

Protective factors against IOP rise that might influence a clinician away from treatment include IOL in-the-bag implantation for a long period of time, smaller capsulorhexis and less power used. No controlled trials are available to provide evidence for specific timeframes or power levels used to minimize risk. However, Keates et al showed 4% of non-glaucoma patients with preoperative pressures below 20 mm Hg had a postoperative rise in IOP to greater than 30 mm Hg. In this study, average total energy used was 101 mJ. One might expect using perhaps under 20 mJ to cause a smaller increase in IOP. Smith et al suggests, albeit without any specific clinical evidence, that adhesions between PC-IOL and capsule remnants would take weeks to months to form a protective barrier against capsulotomy complications.

Retinal Lesions

Although the exact mechanism for the higher incidence of retinal detachment after Nd:YAG capsulotomy is unclear, most proposed mechanisms involve effects on the vitreous such as liquefaction and rupture of the anterior hyaloid face. The estimated risk of detachment is four times higher after laser capsulotomy. Risk factors for developing retinal detachment include high myopia, lattice degeneration with associated holes, greater use of laser energy, and larger capsulotomy size. Adhesions between in-the-bag placed IOL and the posterior capsule over time are postulated to induce some level of protection. One may also postulate that patients who have already had PVD without developing detachment might be afforded some protection from any additional risk from a laser procedure.

Retinal lesions, if considered suitable for treatment may be easier to locate and treat a short period after the Nd:YAG procedure.

Performing Nd:YAG Capsulotomy (Fig. 1)

DILATION OF PUPIL PRIOR TO TREATMENT

The principle of leaving the pupil undilated is that the eye can be treated in physiological conditions, with laser applied only to the central functional visual axis with greater ease resulting in a perhaps smaller but equally effective capsular opening. This would theoretically result in a lower amount of energy being applied, hence fewer side effects.

However, there is some evidence to suggest that although smaller centralized capsulotomy openings are as effective as larger openings in terms of effect

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Evidence-based guidelines for customizing Nd:YAG capsulotomy –
“The Six Big Issues”
T M Aslam 2003

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| ISSUE 3 | Is prophylactic treatment of retinal atrophic holes / lattice degeneration necessary? | No treatment atrophic holes / lattice degeneration |
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| ISSUE 4 | What anterior / posterior direction should laser be directed? | Aim slightly posterior to capsule. |
| | (Taking into account machine settings) | • Clinician concerned about lens pitting |
| | | • Silicone lenses |
| | | • Many previous pits |
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| ISSUE 5 | What capsulotomy size and energy should be used? | Small capsulotomy with minimum power possible |
| | | • Patient has general risk factors for CME, RD |
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| | Larger capsulotomy, still with minimum power possible | • No risk factors for CME, RD |
| | | • IOL in the bag implantation for long period of time |
| | | • Complaints of glare |

| ISSUE 6 | When should any required re-treatment / extra treatment be given? | When feasible, after deciding it is necessary? |
| | | • Elschnig pearl PCO, smooth edged contour to the capsulotomy |
| | | • Minimal enlargement required |
| | Wait one month before re-treatment | • Preoperative fibrous plaques or capsular striae |
| | | • Highly irregular postoperative capsular borders |
| | | • Concern about excessive laser power use |

Fig. 1. Evidence-based guidelines for customizing Nd:YAG capsulotomy—the six big issues.
on visual acuity, a larger capsulotomy opening with a dilated pupil might be necessary to alleviate symptoms of glare.\textsuperscript{59} It is postulated that these symptoms are caused by capsule fragments at the edge of the opening increasing forward light scatter.

A dilated pupil may also be advantageous in that it may expose effective areas to treat that may otherwise be hidden. Depending on the development of the capsulotomy borders, peripheral areas may be the most appropriate for laser treatment in order to form an adequate central aperture.

Smith et al\textsuperscript{173} dilate pupils but draw a diagram of PCO landmarks as they appear with undilated pupil to help assess extent of capsulotomy required.

**USE OF CONTACT LENS**

Use of a contact lens decreases light reflections and can help with stabilization of the patient’s globe. Some practitioners prefer to operate without its use. The lens increases the cone angle of light energy input to the eye resulting in a smaller focal spot.\textsuperscript{124} Although no controlled studies have demonstrated any benefit of using lens in terms of potential side effects, if the cone angle is larger, as with a contact lens, the area of optical breakdown is shorter, with less theoretical subsequent propagation of the acoustic shock wave into the eye.\textsuperscript{115}

**DIRECTING THE LASER**

Many of the papers on Nd:YAG capsulotomy discuss the problem of IOL damage by pitting or cracking\textsuperscript{27,192} and stress the importance of keeping damage to a minimum, for example by aiming the laser beam slightly posteriorly\textsuperscript{124} or by starting off treatments away from the central visual axis.\textsuperscript{198}

All lenses have different thresholds for damage with laser. Trinaverat et al found that silicone lenses were most easily damaged than acrylic than PMMA.\textsuperscript{188} Lenses in which posterior capsule was most closely opposed to the lens were shown to be less protective against pitting than lenses that offer the clinician a greater margin of error, such as convex-concave lenses which permit a small amount of separation between posterior capsule and lens.\textsuperscript{47,125} It should be noted however that although lens pitting and cracks are a stark visual reminder of the power of laser being administered to the eye, these lesions have not been shown to cause any significant loss of visual function even if central.\textsuperscript{18,84,176} Furthermore, directing the laser light more posteriorly may be simply redirecting the energy to an area where its effects might not be as immediately and easily seen, but where long term visual function may be compromised by retinal detachment or CME.

Smith et al used fluorphotometry studies to show that damage to the anterior vitreous face leads to disruption of the barrier known to be protective against retinal detachment and CME.\textsuperscript{173} They further propose that laser damage should be directed more anteriorly to avoid this structure, and the risks that damage to it produces, with marks on the IOL accepted preferentially to vitreous penetration.

**PATTERN OF LASER TREATMENT**

There are no prospective controlled trials comparing methods of capsulotomy in similarly graded opacified posterior capsules. Many authors promote the use of a cross pattern in the center of the visual axis, with the clinician starting off on both axes away from the center to avoid pitting the lens centrally.\textsuperscript{59,75,100,124} It has been suggested, though not scientifically proven, that the procedure may be facilitated if laser is fixed along stress lines, because the capsule will retract after it is disrupted.\textsuperscript{124} The same authors comment that circular application of laser should be avoided as it may result in large capsular flaps that are difficult to remove and cause visual disturbance.\textsuperscript{124} Another suggestion is to use an inverted U-shape of around 3 mm in diameter, where the flap of the U-shape retracts down over time to reveal a clear central visual axis. By this method the author claims to avoid chances of pitting of central visual axis.\textsuperscript{198}

Many articles on capsulotomy were deficient in that they did not mention details of Nd:YAG capsulotomy technique. Any report considering either beneficial or unwanted effects of capsulotomy should ideally comment on the grade of capsular opacification of the capsules treated, the pattern of laser application, and details of the energy used. This was rarely found in the current scientific literature reviewed.

**CAPSULOTOMY SIZE AND LASER ENERGY**

Clinical requirements of capsulotomy size are important as patients subjected to lower amounts of laser energy for perhaps a smaller capsulotomy may benefit from fewer complications of retinal detachment, IOP rise,\textsuperscript{8,33,89,155} and perhaps to less CME.\textsuperscript{173} Risk of IOL dislocation may be significantly less, especially with plate haptic silicone IOLs.

Theoretical optical considerations regarding capsulotomy size were discussed by Holladay et al in 1984, early in the advent of Nd:YAG capsulotomy.\textsuperscript{72} They suggested that the minimum theoretical size for a capsulotomy is 2.4 mm in diameter, with later authors agreeing on this theoretical prediction.\textsuperscript{38} Despite this, diffraction does not limit visual acuity to below 6/6 vision until 1.4 mm.\textsuperscript{29} They also hypothesized that a smaller capsulotomy would cause
decreased image intensity and increased problems with glare. A smaller capsulotomy (2–3 mm) has been shown in clinical trials to be as good as larger openings (5–6 mm) in terms of visual acuity. Conversely, Aslam et al found no correlation between size of capsulotomy created with laser treatment and subsequent improvements in acuity, contrast sensitivity or objective glare measurements. He studied 36 cases of capsulotomies that had no residual obscuring strands of capsule remnant, ranging from 1.25–4.5 mm diameter.30

Although still under some contention, it may be that small capsulotomies done without dilating the pupil may cause forward light scatter from capsule remnants and subsequent glare symptoms.

RETREATMENTS

A clinician may opt to postpone further treatment to a capsule if a small opening has already been formed and he wishes to avoid potentially increased risks by applying more energy. Visual function tests may later reveal however that there has not been a satisfactory improvement in vision, prompting plans for further laser application. Alternatively, visual acuity may have improved satisfactorily leaving persistent glare symptoms that a larger opening may cure.30 There is little research detailing the effect of separating treatment into two or more applications. Capone et al found mean capsulotomy area increased by 32% (range 0–134%) after laser, tending toward smoothing of edges and becoming more circular. Mean follow-up was 6 weeks post-discission. Increase in capsulotomy area was most dramatic in eyes demonstrating evidence of preoperative capsular traction (fibrous plaques and capsular striae) and highly irregular capsular borders immediately post-discission. There was less change in opening area with Elschnig pearl PCO and when there was a smooth edged contour to the capsulotomy immediately post-discission. Hu et al found the increase in size of a capsulotomy to continue progressively for 1 month and then stabilize.75

If retreatments are to be considered it may be sensible to wait 1 month for full effect of enlargement of the capsulotomy to be seen, especially if the patient falls into a category in which enlargement is often seen (preoperative fibrous plaques and capsular striae and highly irregular postoperative capsular borders).

Conclusions

Despite the wide range of reported complications, Nd:YAG capsulotomy has become the preferred mode of treatment for PCO since its introduction over 20 years ago. It has proven to be an effective and safe alternative to surgical discission. More research is needed to determine the risks associated with modern laser machines, laser techniques, and with current trends in cataract surgery and intraocular lenses. However, knowledge of the research base in this field can help treating physicians to tailor their management to individual patients, optimizing visual results of Nd:YAG capsulotomy and keeping potential risks to a minimum.

Method of Literature Search

Searches were done on MEDLINE/Ovid/EMBASE as well as manual search. Searchwords used were Nd:YAG, YAG, laser, capsulotomy, PCO, posterior capsule opacification and years 1975 to present were included in the search. Additional sources were articles cited in the reference lists of other articles. All articles relevant to the field were considered for the review. Foreign literature was reviewed by the translation of full texts with the help of translators. There were no articles that had to be omitted on the basis of language.

References

ND:YAG LASER CAPSULOTOMY


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