Original Article

Neodymium-Yttrium Aluminium Garnet Laser Capsulotomy Energy Levels for Posterior Capsule Opacification

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Abstract

Purpose: To study factors affecting laser energy levels required for neodymium: yttrium aluminium garnet (Nd: YAG) laser capsulotomy and to evaluate whether any correlation exists between applied laser energy levels and complications.

Methods: The present study examined 474 consecutive patients for a number of factors including age, type of posterior capsule opacification (PCO), material and fixation of intraocular lens (IOL) and complication rates, versus energy levels used for Nd: YAG laser capsulotomy.

Results: Mean patient age was 55.6 ± 8.7 years and mean follow up period was 22.9 ± 4.5 months. IOL biomaterial (KW ANOVA; $P = 0.173$) and patient's age ($P = 0.246$) did not significantly influence total laser energy requirement for capsulotomy. However, total laser energy levels were significantly higher (KW ANOVA; $P < 0.001$) with fibro-membranous and fibrous subtypes of PCO. Complications such as IOL pitting, intraocular pressure (IOP) elevation, uveitis, retinal detachment (RD) and cystoid macular edema (CME) were significantly more common when higher energy levels was used. The mean total energy in patients with RD was 77.7 ± 17.7 mJ as compared to 43.4 ± 26.9 mJ in the rest of the cohort. RD was more common in patients with higher axial length [$n = 7$ (63%)] ($P < 0.001$).

Conclusion: Type of PCO significantly influenced laser energy levels required for capsulotomy, whereas IOL biomaterial and fixation did not. Complications such as IOL pitting, uveitis, IOP elevation, RD and CME was significantly more common when total laser energy was higher. It is recommended that the lowest possible single pulse laser energy be used for capsulotomy to minimize complications.

Keywords: Intraocular Lens; Laser Capsulotomy; Posterior Capsule Opacification

J Ophthalmic Vis Res 2015; 10 (1): 37-42.

INTRODUCTION

Posterior capsule opacification (PCO) is one of the most common visually disabling complications of cataract surgery. However, due to improvements in surgical technique, intraocular lens (IOL) material, design and selective use of therapeutic agents, there has been a reduction in the incidence of PCO. Having said this, PCO and subsequent Neodymium yttrium aluminium garnet laser (Nd: YAG) capsulotomy rates may be much higher in communities where a sizeable population still do not have access to phacoemulsification and modern IOLs.[1]

Various factors such as age and PCO thickness may affect the required power for Nd: YAG laser to rupture an opacified capsule. While Nd: YAG laser capsulotomy may significantly influence the ability of a vitreoretinal

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Received: 10-05-2013 Accepted: 12-05-2014

Access this article online
Quick Response Code:
Website: www.jovr.org
DOI: 10.4103/2008-322X.156101

surgeon to visualize the peripheral fundus in patients at risk of retinal detachment (RD) on one hand, it may itself lead to RD and cystoid macular edema (CME), on the other. The precise mechanisms leading to retinal breaks and RD after laser capsulotomy are not known. Many investigators believe that laser energy induces vitreous liquefaction, posterior vitreous detachment or both, which might create new breaks or enable pre-existing asymptomatic breaks to progress to RD.[2,3] The impact of Nd: YAG laser energy *per se* on the rate of complications has not been studied extensively and a causal relation has not been established.

The purpose of the present study was to analyze the impact of factors such as patient's age, IOL biomaterial, IOL fixation and PCO subtypes on laser energy levels required for capsulotomy and to evaluate whether any correlation exists between the amount of laser energy applied and complications rates.

METHODS

This study was performed at Indira Gandhi Medical College and Hospital and Laser Eye Clinic Noida, India and included a cohort of 474 consecutive eyes with visually significant PCO, referred for Nd: YAG laser capsulotomy, from February 2008 to November 2010. More than 70% of Nd: YAG laser capsulotomies of the region and 90% retinal detachment surgeries are performed at this referral hospital. Written informed consent was obtained from all patients based on the Helsinki protocol. The local ethics committee and institutional review boards approved the trial.

Patients were enrolled if there was reduction in corrected distance visual acuity (CDVA) by two or more Snellen lines, glare disabilities or monocular diplopia. As a rule, patients with PCO were considered for capsulotomy after a minimum period of 3 months following uneventful cataract surgery. Patients with history of retinal detachment (RD) in the fellow eye, peripheral retinal degenerations, retinal breaks, past history of vitreoretinal surgery, diabetic retinopathy and follow up less than 9 months were excluded.

The preoperative protocol included recording corrected distance visual acuity (CDVA). The pupils were dilated with tropicamide 0.5% and phenylephrine 10% drops. Fixation of IOL was noted in each case. The posterior pole was examined with a 90 diopter (D) lens while the peripheral retina was evaluated by binocular indirect ophthalmoscopy using a 20 D lens with scleral indentation.

The impact of factors such as age, subtype of PCO, and type and fixation of IOL on energy levels used for Nd: YAG laser capsulotomy was studied. We also evaluated whether any correlation exists between laser energy delivered to the treatment site and complications rates.

Technique

A Q-switched Nd: YAG laser system (Visulas YAG II^{Plus}, Carl Zeiss, Germany), with wavelength of 1064 nm and pulse length of <4 ns (2-3 ns) was employed for this study. Nd: YAG laser capsulotomy was performed using an Abraham lens with hydroxypropyl methylcellulose as the coupling agent.

Before starting the procedure, one drop of 4% xylocaine was instilled into the conjunctival cul-de sac. The pupils were fully dilated and the aim was to create a capsulotomy of about 4 mm in size. A central cruciate pattern in an upward-downward direction was used.[4] The aiming beam was focused slightly posterior to the posterior capsule. The optical center of the IOL was matched with the center of the opening. The starting initial energy level (0.3-10 mJ), number of pulses used to create capsulotomy and summated laser energy was noted in each case.

Patients were visited the on first, third and seventh postoperative days, then weekly for two weeks, monthly for two months and every three months thereafter. The postoperative regimen included topical betamethasone 0.1%, every two hours, tapered over 2-3 weeks depending on the inflammatory response. Antiglaucoma medications were not given prior to capsulotomy to any patient. At each follow up visit, CDVA was checked and intraocular pressure (IOP) was measured by Goldmann applanation tonometry. Detailed fundus examination including indirect ophthalmoscopy was one week and one month after laser capsulotomy and repeated at three month intervals.

RESULTS

A total of 42 patients could not complete the study due to death, health or social reasons. Records of 474 patients who received Nd: YAG laser capsulotomy were evaluated; these included 244 (51%) female and 230 (49%) male subjects. Mean follow-up period was 22.9 ± 4.5 months.

Visual Acuity

Snellen visual acuity was converted to logMAR units for comparisons. Mean preoperative CDVA was 0.85 ± 0.22, mean visual acuity on day one was 0.27 ± 0.18 logMAR and mean final CDVA was 0.21 ± 0.21 logMAR. There was a significant improvement in vision after the procedure ($P < 0.001$) [Table 1]. At final follow-up, 95.6% of patients had CDVA of 0.5 or better (≥6/12). CDVA remained less than 6/60 due to cystoid macular edema and retinal detachment. Table 1 shows the percentage of patients at each level of CDVA.

Laser Energy and Age

Mean age was 55.6 ± 8.7 (range, 40-76) years. Although laser energy levels were slightly higher in younger subjects, the difference between various age groups was not significant ($P = 0.246$).

Laser Energy and PCO Subtypes

There was a significant difference in the initial and total laser energy levels required for capsulotomy with different subtypes of PCO. The mean starting initial energy (single pulse) for membranous (pearl form), fibrous and fibro-membranous PCO was 1.8 ± 1.1, 2.8 ± 1.1 and 2.5 ± 0.8 mJ respectively (Mann Whitney test; $P < 0.001$). Table 2 shows there was a significant difference in mean total energy levels in these subtypes (KW ANOVA: $P < 0.001$).

Laser Energy and IOL Biomaterial

The IOL biomaterial (silicone, hydrophobic acrylic, hydrophilic acrylic and PMMA) did not significantly influence the total laser energy required to create a capsulotomy (KW ANOVA; $P = 0.173$). On the contrary, the damage thresholds of IOLs were significantly different (silicone < acrylic < PMMA). Table 3 shows that for equivalent total laser energy levels, silicone IOLs were more vulnerable to pitting and damage.

Laser Energy and IOL Fixation

Out of 474 patients, 390 (82.3%) had in-the-bag IOL fixation, 50 (10.5%) had sulcus IOL fixation and 34 (7.2%) had sulcus-bag IOL fixation, respectively. Mean laser energy levels for in-the-bag, sulcus-sulcus and sulcus-bag fixated IOLs were 44.3 ± 27.1 mJ, 46.4 ± 23.7 mJ and 49.7 ± 18.2 mJ, respectively ($P = 0.783$).

Table 1. Percentage of patients at each level of corrected distance visual acuity

CDVA (logMAR)	*n* (%)	
	Preoperation	Postoperation
0-0.25	0 (0)	384 (81)
0.26-0.50	56 (11.8)	69 (14.6)
0.51-0.75	108 (22.8)	04 (0.8)
>0.76	310 (65.4)	17 (3.6)
Total	474 (100)	474 (100)

logMAR, logarithm of minimum angle of resolution; CDVA, corrected distance visual acuity

Table 2. Mean total laser energy levels (mJ) for subtypes of posterior capsule opacification

		SEL (mJ)			
Type of PCO	N	Mean	SD	Minimum	Maximum
Membranousb (pearl form)	280	22.42	4.77	16	69
Fibrous	105	64.55	6.88	34	92
Fibro-membranous	89	68.83	8.84	21	98

KW ANOVA: $P < 0.001$. mJ, millijoule; PCO, posterior capsule opacification; SD, standard deviation; KW ANOVA, Kruskal–Wallis nonparametric analysis of variance; SEL, summated energy level

Laser Energy and Complications

The total energy required to create the capsulotomy was compared with complications observed during the course of the study [Table 4]. There was a significant association between laser energy levels and complications such as IOP spikes, uveitis, hyaloid face rupture, IOL pitting, retinal detachment and cystoid macular edema ($P < 0.001$). In general, mean laser energy was significantly higher (66.3 ± 25.5 mJ) in eyes developing complications as compared to the group without any complications (36.6 ± 23.7 mJ) (Mann Whitney test; $P < 0.001$).

IOL Pitting

The incidence of IOL pitting was 7.8%. The mean total laser energy level in eyes with IOL pitting ($n = 37$) was 61.6 ± 26.4 mJ as compared to 42.8 ± 26.7 mJ in eyes without IOL pitting ($n = 437$). Silicone IOLs had a higher incidence of pitting as well as a lower threshold for laser induced damage [Table 4] ($P < 0.001$).

IOP Elevation

The incidence of IOP elevation was 12.6%. Overall, 1.3% patients had medically controlled glaucoma prior

Table 3. Mean total laser energy levels for different types of intraocular lenses

Type of IOL	Pitting *n* (%)	Mean SEL (mJ)	SD
Silicone	15 (40.5)	44.35	26.59
Hydrophobic acrylic	05 (13.5)	41.06	26.83
Hydrophilic acrylic	06 (16.2)	44.42	27.49
PMMA	11 (29.7)	49.23	27.68

KW ANOVA; $P = 0.173$. IOL, intraocular lens; SEL, summated energy level; SD, standard deviation; KW ANOVA, Kruskal–Wallis nonparametric analysis of variance; PMMA, polymethylmethacrylate

Table 4. Mean total laser energy in groups with and without complications

Complication	Group	*n*	SEL (mJ)	*P*
Uveitis	Absent	427	42±26.4	<0.001
	Present	47	65±24.8	
IOP spikes	Absent	414	42.3±26.6	<0.001
	Present	60	75.8±18.7	
Hyaloid phase rupture	Absent	432	41.2±25.8	<0.001
	Present	42	57.7±26.8	
CME	Absent	446	42.2±26.2	<0.001
	Present	28	70.8±20	
RD	Absent	463	43.4±26.9	<0.001
	Present	11	77.7±17.7	
IOL pitting	Absent	437	42.8±26.7	<0.001
	Present	37	61.5±26.3	

SEL, summated energy level; mJ: millijoule; IOP, intraocular pressure; CME, cystoid macular edema; RD, retinal detachment; IOL, intraocular lens to capsulotomy. Mean IOP on the post-operative day one was 21.5 ± 6.6 mmHg. Mean laser energy in the subgroup with IOP elevation (n = 60) was 57.8 ± 26.8 mJ as compared to 42.3 ± 26.6 mJ in eyes with no IOP elevation (n = 414) (P < 0.001). IOP returned to normal limits at 2 weeks in most patients following topical treatment with 0.5% apraclonidine eye drops twice daily. Out of 6 patients who developed sustained IOP elevation, two had medically controlled glaucoma. These were referred to the glaucoma clinic for further management.

Uveitis

The incidence of anterior segment inflammation on post-operative day one was 9.9%. Overall, 1.9% of the patients had a history of prior uveitis. Mean total laser energy in the subgroup with uveitis (n = 47) was 64.9 ± 24.8 mJ as compared to 42.0 ± 26.4 mJ in eyes without uveitis (n = 427). Betamethasone 1% eye drops, tapered over 2-3 weeks, resulted in resolution of inflammation in all but 4 eyes. Out of these, two patients had prior uveitis. Oral prednisolone 1 mg/kg/day (tapered over 5 days) resulted in resolution of uveitis.

Cystoid Macular Edema

The incidence of CME was 2.9%. The mean total laser energy in eyes with CME (n = 14) was 77.8 ± 17.7 mJ versus 42.2 ± 26.2 mJ in the group without clinical CME (n = 460) (P < 0.001)

Retinal Detachment

Out of 474 eyes, 11 patients developed rhegmatogenous RD during follow up (2.3%). The mean duration of RD after capsulotomy was 11.7 ± 0.8 months. RD was more common in patients with higher axial length [n = 7 (63%)] (P < 0.001). Mean total laser energy in the RD group (n = 11) was 70.2 ± 20.0 mJ as compared to 43.4 ± 26.9 mJ in the group with normal retina (n = 463) (P < 0.001). Table 5 shows baseline characteristics of patients with RD.

DISCUSSION

Nd: YAG laser capsulotomy is the mainstay of treatment for PCO.[5] However, surgical peeling and aspiration of pearls may be an alternative in myopic eyes.[6] There has been a reduction in the overall rate of complications following Nd: YAG laser capsulotomy. This could be attributed to better understanding of the mechanisms of laser induced damage and recognition of the fact that one should limit the total amount of laser energy delivered to the treatment site.[7,8]

The aim of capsulotomy in the present study was to clear the visual axis by creating an opening in the opacified posterior capsule by focusing Nd: YAG laser pulses of a few millijoules (mJ) in energy with duration of 2-3 nanoseconds, posterior to the posterior capsule. There are only a few published studies in the literature which have evaluated the effects of laser energy *per se* on complication rates, and the effect of factors such as IOL type and fixation, and type of PCO on energy levels. This prospective study evaluated the effect of these factors on the level of energy used for capsulotomy and the correlation between total laser energy levels and the rate of complications.

Nd: YAG capsulotomy is associated with significant anterior and posterior segment complications. Some studies recommend that side effects are more pronounced when higher single pulse energy levels are used rather than higher total laser energy.[9]

In a retrospective study on 215 eyes with PCO, Bhargava et al found that different PCO subtypes required different initial and total laser energy levels depending on thickness of the posterior capsule (1.8, 3.1 and 2.7 mJ for membranous, fibrous, fibro-membranous opacities respectively). The authors recommended lower single pulse energy levels rather than higher total energy in order to minimize the rate of complications.[10] The starting mean initial energy in the present study was 1.8 mJ and 2.8 mJ for pearl and fibrous forms of PCO respectively, which was comparable to the

Table 5. Baseline characteristics of patients with retinal detachment

Case number	Age	AL	Lattice	IEL (mJ)	SEL (mJ)	PCO subtype	Duration (months)
1/male	56	24.0	No	2.8	80	Fibrous	15
2/male	68	26.5	Yes	2.1	40	Membranous	12
3/female	64	27.8	Yes	2	80	Fibrous	13.4
4/male	72	23.4	No	3.2	94	Fibrous	14.6
5/female	68	26.5	Yes	2.2	36	Membranous	4.0
6/female	80	23.6	Yes	3	86	Fibrous	11.2
7/male	49	27.1	Yes	2.1	40	Membranous	6.2
8/female	52	26.7	Yes	3.4	92	Fibrous	11.6
9/male	76	28.0	Yes	2.3	36	Membranous	12.4
10/female	66	23.2	No	3.1	90	Fibrous	14.6
11/female	57	24	NO	3.4	98	Membranous	13.2

AL, axial length; IEL, initial energy level/starting initial energy; mJ, millijoule; SEL, summated energy level; PCO, posterior capsule opacification results of the study by Bhargava et al There was also a significant difference ($P < 0.001$) in the total laser energy levels required to create capsulotomy in fibrous and pearl subtypes of PCO. This finding is similar to the observation by Bhargava et al Hawlina G and Drnovsek-Olup performed capsulotomy in 53 eyes with an initial energy of 1.6 mJ. Mean total energy in their study was 104.72 mJ, which is comparable to our study.[11] Hood et al described the use of Nd: YAG laser to lyse residual cortex after phacoemulsification with mean pulse energy of 1.7 ± 0.5 mJ and total energy of 159 ± 114 mJ.

The incidence of IOP rise was significantly more in the group with higher total energy levels (226 ± 233 mJ).[12] In a series of 30 patients with PCO, Ari et al evaluated the effect of energy levels for Nd: YAG laser capsulotomy on IOP and macular thickness and found that the severity and duration of IOP rise was less when the total energy was less than 80 mJ.[13,14] In another study, Karahan et al evaluated the effect of capsulotomy size on IOP and macular thickness. IOP rise was significantly greater in the large capsulotomy group (with higher laser energy), i.e. 3.4 ± 0.3 versus 4.6 ± 0.5 mmHg.[15] The results of these studies further substantiate the observations of the present study.

The present study suggests that neither age nor the type of IOL (silicone, hydrophobic acrylic, hydrophilic acrylic and PMMA) have a significant effect on the total laser energy required to create a capsulotomy. However, different IOL materials had different damage thresholds and consequent pitting and cracks (PMMA > acrylic > silicone). IOL damage following capsulotomy has been attributed to faulty focusing of laser beam, close proximity of the IOL to the posterior capsule and inherent properties of IOL materials. However, laser energy *per se* also had a significant effect on IOL damage. This was evident by the fact that total laser energy was significantly higher ($P < 0.001$) in the group of eyes in which pitting was seen. A similar observation was made by Saffra et al in an *in-vitro* analysis of Nd: YAG laser damage to hydrophilic IOLs.[16] Thus, we advise focusing the laser beam posterior to the posterior capsule, and setting the laser beam to the minimum possible energy level.

Auffarth et al analysed energy levels of Nd: YAG laser capsulotomy for secondary cataracts in a series of 172 patients and found that the total laser energy was significantly higher with sulcus fixated IOL's.[17] This observation was similar to the results of the present study.

The incidence of CME following Nd: YAG laser capsulotomy ranges from 0.6-4.4%. Total laser energy levels in the present study were significantly higher in the group of eyes with CME. On the contrary, only two of the eleven eyes with CME had increased post-procedural inflammation. Altiparmak et al measured foveal thickness with optical coherence tomography following Nd: YAG laser capsulotomy in a series of 54 eyes. The authors did not find any correlation between foveal thickness and total laser energy or any change in foveal thickness at 12 months.[18] Smaller sample size in their study could explain this difference.

The results of the present study suggest a significant relation between laser energy levels and retinal detachment. Mean total energy was significantly higher in patients with RD (77.7 ± 17.7 versus 43.4 ± 26.9 mJ). Although RD was more common in patients with longer axial length (>24 mm), patients with normal axial length (22-24 mm) and without any pre-existing retinal breaks but higher total laser energy levels (mean, 89.6 ± 4.26 mJ) also developed RD [Table 5]. Alimanović-Halilović analysed complications in the posterior segment after Nd: YAG laser capsulotomy and found a significant association between total laser energy levels and complications such as RD and CME, and the collative connections were positive and strong.[19] It appears that high total laser energy may be an independent risk factor for RD following laser capsulotomy. However, studies on a larger sample size may be required to further substantiate this observation. It is advisable to avoid large size capsulotomies in patients with high axial length.

In conclusion, the results of the present study suggest that a correlation exists between total Nd: YAG laser energy levels delivered to the treatment site and the rate of intraocular complications. We recommend lower starting single pulse energy levels for capsulotomy to minimize the incidence of adverse effects.

ACKNOWLEDGEMENTS

Dr. Puneet Gupta for statistical analysis.

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How to cite this article: Bhargava R, Kumar P, Phogat H, Chaudhary KP. Neodymium-yttrium aluminium garnet laser capsulotomy energy levels for posterior capsule opacification. J Ophthalmic Vis Res 2015;10:37-42.

Source of Support: Nil. **Conflict of Interest**: None declared.