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Original Research Article

TO ESTIMATE THE MEAN ND YAG LASER CAPSULOTOMY ENERGY LEVELS FOR DIFFERENT SUBTYPES OF POSTERIOR CAPSULAR OPACIFICATION (PCO)

Raghavendra R[1], Suchi M[2], Athira P.K[3]

[1]*Professor, Department of Ophthalmology, Mysore Medical College and Research Institute, Mysuru, Karnataka, India*
[2]*Senior Resident, Department of Ophthalmology, Mysore Medical College and Research Institute, Mysuru, Karnataka, India*
[3]*Junior Resident, Department of Ophthalmology, Mysore Medical College and Research Institute, Mysuru, Karnataka, India*

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Corresponding Author:
Dr. Suchi M,
Senior Resident, Department of Ophthalmology, Mysore Medical College and Research Institute, Mysuru, Karnataka, India.
Email: suchi.mpushpa@gmail.com

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ABSTRACT

Background: Posterior capsular opacification (PCO) is the most common delayed complication following cataract surgery and remains a leading cause of reduced visual acuity in pseudophakic patients. Nd YAG laser posterior capsulotomy is the standard treatment for visually significant PCO. However, the laser energy required varies according to the morphological subtype of PCO, and concerns persist regarding energy-related postoperative complications such as intraocular pressure (IOP) elevation and anterior segment inflammation. The objective is to estimate the mean Nd YAG laser capsulotomy energy levels required for different subtypes of PCO and to evaluate the correlation between total cumulative laser energy and early postoperative complications.
Materials and Methods: This single-centre comparative study included 70 patients with visually significant PCO. All patients underwent detailed preoperative evaluation, including best-corrected visual acuity and IOP measurement. PCO was classified into Elschnig pearls, fibrous, and mixed types. Nd YAG laser capsulotomy was performed using a standardized technique, and initial energy, final energy, number of pulses, and total cumulative energy were recorded. Patients were followed up to six months for assessment of IOP and postoperative complications. Data were analyzed using descriptive statistics, one-way ANOVA, and Pearson correlation.
Results: Elschnig pearls were the most common subtype (42.9%), followed by fibrous (34.3%) and mixed (22.9%). Fibrous PCO required significantly higher total cumulative energy compared to other subtypes ($p < 0.001$). No significant correlation was found between total cumulative energy and IOP at 1 hour or day 1 post-procedure. Mild iritis was observed in 5.7% of cases on postoperative day 1, with no persistent or late complications during follow-up.
Conclusion: Laser energy requirements vary significantly with PCO subtype; however, cumulative energy was not associated with increased early complications. Nd YAG laser capsulotomy remains a safe and effective modality when energy settings are appropriately titrated.
Keywords: Posterior capsular opacification, Nd YAG laser capsulotomy, Total cumulative energy, Intraocular pressure, Complications, PCO subtypes.

INTRODUCTION

Posterior capsular opacification (PCO) remains the most common delayed complication following cataract surgery, despite significant advancements in surgical techniques and intraocular lens (IOL) design.[1] It results from proliferation, migration, and epithelial–mesenchymal transformation of residual lens epithelial cells over the posterior capsule.[2] The reported incidence varies depending on surgical technique and IOL material, but clinically significant PCO requiring Nd YAG laser capsulotomy has been reported in 10–30% of patients within 2–5 years after surgery.[3,4]

Morphologically, PCO is classified into Elschnig pearls, fibrous type, and mixed variants.[5] Pearls are characterized by proliferative balloon-like epithelial cells, whereas fibrous PCO consists of collagenous plaques and capsular wrinkling, which may be denser and more resistant to laser disruption.[6] These morphological differences influence laser energy requirements during treatment.[7]

Nd YAG laser posterior capsulotomy is considered the gold standard for managing visually significant PCO.[8] The procedure restores the visual axis and significantly improves visual acuity.[9] However, the total laser energy delivered varies widely depending on PCO density and subtype.[7,10] Higher energy exposure has been hypothesized to increase the risk of postoperative complications such as intraocular pressure (IOP) spikes, anterior uveitis, cystoid macular edema (CME), retinal detachment (RD), and IOL damage.[8,11]

Transient elevation of IOP is the most frequently reported early complication, typically occurring within the first few hours after the procedure.[12] Although several studies have attempted to correlate total cumulative energy with IOP rise and inflammatory response, the relationship remains inconsistent.[13,14] Moreover, the overall safety profile of Nd YAG laser capsulotomy is well established, with serious complications being relatively uncommon.[11,15]

Given the clinical importance of optimizing laser parameters while minimizing complications, the present study was undertaken to evaluate the laser energy requirements across different PCO subtypes and to assess their association with early postoperative outcomes.

MATERIALS AND METHODS

This single-centre comparative study was conducted in the Department of Ophthalmology at K.R. Hospital, MMC&RI, Mysore, over a period of six months. Patients presenting to the outpatient department with visually significant posterior capsular opacification (PCO) were screened and enrolled using simple random sampling. The calculated sample size was 70 subjects, derived using a clinically worthwhile effect size of 1.6, a significance level (α) of 0.05, a study power of 80%, and a standard deviation of 4.77 based on previously published literature

Adult patients aged 18 years and above with biomicroscopically detectable PCO and symptomatic visual disturbances such as glare, monocular diplopia, or reduction in best-corrected visual acuity (BCVA) by two or more Snellen lines were included. Patients with high myopia, history of retinal detachment or vitreoretinal surgery in the fellow eye, diabetic retinopathy, peripheral retinal degeneration, retinal breaks, intraocular lens (IOL) displacement, sulcus-fixated IOL, posterior capsular rent, or active ocular disease were excluded from the study.

All enrolled patients underwent a comprehensive ophthalmic examination prior to the procedure. BCVA was assessed using Snellen's visual acuity chart. Intraocular pressure (IOP) was measured using Goldmann applanation tonometry. Pupillary dilatation was achieved using tropicamide combined with phenylephrine eye drops, following which slit-lamp biomicroscopy was performed to document the type of PCO and the position of the IOL. Posterior segment evaluation was conducted using a 90-diopter lens for posterior pole examination and a 20-diopter lens for peripheral retinal assessment.

Nd YAG laser posterior capsulotomy was performed after instillation of topical 0.5% proparacaine hydrochloride. A capsulotomy measuring approximately 3.5–4 mm in diameter was created using a cruciate pattern. The initial energy setting, final pulse energy, total number of pulses delivered, and total cumulative energy were recorded for each patient.

Postoperatively, all patients were prescribed a topical antibiotic-steroid combination (moxifloxacin with dexamethasone) administered every two hours, which was gradually tapered over two to three weeks depending on the inflammatory response. Patients were followed up on postoperative day 1, day 7, weekly for two weeks, and monthly thereafter for six months. At each visit, BCVA and IOP were recorded, and detailed anterior segment and fundus examinations were performed to identify any complications.

Data were entered into Microsoft Excel and analyzed using SPSS. Continuous variables were expressed as mean and standard deviation, while categorical variables were presented as frequency and percentage. One-way analysis of variance (ANOVA) was used to compare laser energy parameters among different PCO subtypes. Pearson correlation analysis was performed to assess the relationship between total cumulative energy and postoperative IOP. Chi-square tests were used for categorical comparisons where appropriate. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 70 patients who underwent Nd YAG laser capsulotomy were included in the study. The mean age of the study population was 64.0 ± 9.0 years. Females constituted 55.7% (n = 39) of the sample, while males accounted for 44.3% (n = 31). The right eye was involved in 52.9% (n = 37) of cases and the left eye in 47.1% (n = 33). The mean duration since cataract surgery was 28.8 ± 11.2 months. Phacoemulsification was the most common surgical technique performed (57.1%), followed by SICS (42.9%). Foldable acrylic intraocular lenses were implanted in 52.9% of patients, while 47.1% had PMMA lenses. The majority of IOLs were positioned in-the-bag (88.6%). The mean pre-laser intraocular pressure was 14.9 ± 1.7 mmHg [Table 1].

Regarding the type of posterior capsular opacification, Elschnig pearls were the most common subtype observed in 42.9% (n = 30) of patients, followed by fibrous PCO in 34.3% (n = 24), and mixed PCO in 22.9% (n = 16) of cases [Table 2].

Analysis of laser parameters revealed statistically significant differences among the PCO subtypes. The mean initial pulse energy was highest in the fibrous group (2.300 ± 0.1745 mJ), followed by the mixed group (2.012 ± 0.1258 mJ), and lowest in the Elschnig pearls group (1.633 ± 0.1647 mJ). Similarly, the mean final pulse energy was significantly higher in fibrous PCO (2.646 ± 0.1865 mJ) compared to mixed (2.375 ± 0.1483 mJ) and Elschnig pearls (2.003 ± 0.1991 mJ). The total number of pulses required was greatest in fibrous PCO (38.42 ± 3.361), followed by mixed (32.88 ± 3.612), and Elschnig pearls (27.43 ± 4.508). Correspondingly, the mean total cumulative energy was significantly higher in fibrous PCO (88.325 ± 9.8848 mJ), followed by mixed PCO (66.175 ± 8.4437 mJ), and lowest in Elschnig pearls (44.947 ± 9.4265 mJ). One-way ANOVA demonstrated statistically significant differences across groups for all laser parameters ($p < 0.001$). Levene's test confirmed homogeneity of variances ($p > 0.05$), and post-hoc Tukey analysis showed significant pairwise differences between all subtypes [Table 3].

Correlation analysis showed no statistically significant relationship between total cumulative energy and intraocular pressure at 1 hour ($r = -0.061$, $p = 0.617$) or on postoperative day 1 ($r = 0.004$, $p = 0.973$). However, a strong positive correlation was observed between IOP at 1 hour and IOP on day 1 ($r = 0.737$, $p < 0.001$), indicating consistency in early postoperative IOP measurements [Table 4].

With respect to postoperative complications, mild iritis was observed in 4 patients (5.7%) on postoperative day 1, while 94.3% of patients had no complications. No immediate complications were noted post-laser, and no complications were observed at day 7, week 2, or during monthly follow-up up to 6 months. No cases of persistent inflammation, cystoid macular edema, or retinal detachment were reported during the follow-up period [Table 5].

Binary logistic regression analysis was performed to assess predictors of day 1 complications. Total cumulative energy ($p = 0.575$), age ($p = 0.592$), PCO density ($p = 0.455$), and duration since surgery ($p = 0.444$) were not statistically significant predictors of mild iritis. The overall model was not statistically significant (Omnibus test $p = 0.796$), with a Nagelkerke R^2 of 0.094. The Hosmer–Lemeshow test indicated good model fit ($p = 0.644$), and the overall classification accuracy was 94.3% [Table 6].

Table 1: Baseline Demographic and Clinical Characteristics (n = 70)

Variable	Mean ± SD or Frequency (Percentage)
Age (Years)	64.0 ± 9.0
Sex	
Female	39 (55.7%)
Male	31 (44.3%)
Eye Involved	
Right	37 (52.9%)
Left	33 (47.1%)
Duration Since Surgery (Months)	28.8 ± 11.2
Type of Cataract Surgery	
Phacoemulsification	40 (57.1%)
SICS	30 (42.9%)
Type of IOL	
Foldable Acrylic	37 (52.9%)
PMMA	33 (47.1%)
IOL Position	
In-the-bag	62 (88.6%)
Sulcus	8 (11.4%)
Pre-Laser IOP (mmHg)	14.9 ± 1.7

Table 2: Distribution of PCO Subtypes (n = 70)

Type of PCO	n (%)
Elschnig pearls	30 (42.9%)
Fibrous	24 (34.3%)
Mixed	16 (22.9%)

Table 3: Nd YAG Laser Parameters According to Type of PCO

Parameter	Elschnig Pearls (n=30)	Fibrous (n=24)	Mixed (n=16)	F value	P value
Initial Pulse Energy (mJ)	1.633 ± 0.1647	2.300 ± 0.1745	2.012 ± 0.1258	116.786	<0.001
Final Pulse Energy (mJ)	2.003 ± 0.1991	2.646 ± 0.1865	2.375 ± 0.1483	82.243	<0.001
Total Number of Pulses	27.43 ± 4.508	38.42 ± 3.361	32.88 ± 3.612	51.689	<0.001
Total Cumulative Energy (mJ)	44.947 ± 9.4265	88.325 ± 9.8848	66.175 ± 8.4437	142.874	<0.001

Levene's test values: All $p > 0.05$ → Homogeneity satisfied, ANOVA p values all < 0.001

Tukey post-hoc: all pairwise comparisons significant

Table 4: Correlation Between Total Cumulative Energy and IOP

Variables	r	P value
Total Cumulative Energy vs IOP at 1 Hour	-0.061	0.617
Total Cumulative Energy vs Day 1 IOP	0.004	0.973
IOP at 1 Hour vs Day 1 IOP	0.737	<0.001

Table 5: Postoperative Complications According to Follow-Up Timeline

Follow-Up Visit	None n	None %	Mild Iritis n	Mild Iritis %
Immediate Post-Laser	70	100	0	0
Day 1	66	94.3	4	5.7
Day 7	70	100	0	0
Week 2	70	100	0	0
Month 1	70	100	0	0
Month 2	70	100	0	0
Month 3	70	100	0	0
Month 4	70	100	0	0
Month 5	70	100	0	0
Month 6	70	100	0	0

Table 6: Binary Logistic Regression for Complications (Mild Iritis)

Variable	B	S.E	Wald	P value	Exp(B)	95% CI
Total Cumulative Energy (mJ)	0.014	0.025	0.315	0.575	1.014	0.966–1.064
Age (Years)	-0.038	0.07	0.287	0.592	0.963	0.839–1.105
PCO Density (Overall)	—	—	1.577	0.455	—	—
Duration Since Surgery (Months)	-0.041	0.054	0.585	0.444	0.96	0.864–1.066

Model Fit: Omnibus Test p = 0.796, Nagelkerke $R^2 = 0.094$, Hosmer-Lemeshow p = 0.644, Overall classification = 94.3%. Model not statistically significant, Total cumulative energy is Not a predictor of complication

DISCUSSION

In the present study, Elschnig pearls constituted the most common subtype of PCO, followed by fibrous and mixed types. Similar morphological distributions have been reported in previous clinical evaluations of PCO patterns.[5,9] The predominance of pearls may reflect ongoing proliferative activity in residual lens epithelial cells.[2]

A statistically significant difference in laser energy parameters was observed among PCO subtypes. Fibrous PCO required the highest initial pulse energy, final pulse energy, number of pulses, and total cumulative energy, followed by mixed and pearl types. This finding aligns with prior observations that fibrotic plaques demand greater photodisruptive energy due to increased capsular density and collagen content.[6,7,10] Bhargava et al. reported similar trends in energy consumption between morphological subtypes[9]. Ari et al. further demonstrated that higher total energy delivery may induce subtle macular thickness changes, emphasizing the need for energy optimization.[10]

The mean total cumulative energy in our study was within the range reported in earlier literature (approximately 40–100 mJ depending on subtype),[8,9,13] confirming the clinical validity of the energy parameters used.

No statistically significant correlation was observed between total cumulative energy and IOP at 1 hour or day 1 post-procedure. These findings are consistent with reports by Parajuli et al. and Ozkurt et al., who found that early IOP elevations were transient and not directly proportional to total energy used.[12,13] The significant correlation between 1-hour and day-1 IOP likely represents physiological IOP fluctuation rather than an energy-dependent phenomenon.

The overall complication rate in this study was low, with only mild anterior uveitis observed on day 1 and no persistent complications during follow-up. Previous studies have reported complication rates ranging from 5–15%, with IOP spikes being the most common adverse event.[8,11,14] Serious complications such as CME and RD are uncommon but documented in large cohort studies.[11,15] The absence of significant late complications in our study reinforces the safety of Nd YAG laser capsulotomy when appropriate patient selection and energy titration are employed.

Overall, the findings of the present study corroborate existing evidence that PCO subtype significantly influences laser energy requirements, while postoperative complications remain infrequent and are not directly determined by cumulative laser energy exposure.

CONCLUSION

The present study demonstrates that Nd YAG laser energy requirements significantly vary according to the morphological subtype of posterior capsular opacification, with fibrous PCO requiring the highest cumulative energy, followed by mixed and Elschnig pearl types. Despite these differences in energy delivery, early postoperative complications were minimal and not significantly associated with total cumulative laser energy. Intraocular pressure changes were transient and did not correlate with energy levels. These findings reaffirm that Nd YAG laser capsulotomy is a safe and effective procedure when appropriately titrated according to PCO subtype, ensuring optimal visual rehabilitation with a low complication profile.

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