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Original Research Article

Risk Factors for Posterior Capsular Opacification After Cataract Surgery: A Retrospective Analysis

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Abstract:

Background: Posterior capsular opacification (PCO) is the most common delayed complication following cataract surgery, leading to reduced visual acuity and quality of life. Understanding its risk factors is essential for prevention and management.

Aim: To identify demographic, ocular, and surgical factors associated with PCO development within three years after cataract surgery.

Methodology: A retrospective case-control study was conducted at the Department of Ophthalmology, Patna Medical College and Hospital, India. Medical records of 154 eyes from 94 patients who underwent phacoemulsification or extracapsular cataract extraction (ECCE) were analyzed. Patients were categorized into PCO (n=68) and non-PCO (n=86) groups. Data collected included age, sex, systemic conditions, ocular parameters, surgical technique, intraocular lens (IOL) type, and postoperative outcomes. Statistical analysis involved chi-square tests and multivariate logistic regression to identify independent risk factors ($p<0.05$).

Results: PCO occurred in 44.2% of eyes, with higher grades correlating with worse visual acuity. Significant risk factors included age <60 years, diabetes, high myopia, harder lens nucleus, ECCE, prior vitrectomy, and hydrophilic IOLs. Sex and eye laterality were not significant.

Conclusion: PCO development is multifactorial, influenced by patient age, systemic and ocular comorbidities, surgical technique, lens characteristics, and IOL material. Recognition of these risk factors can guide surgical planning and IOL selection to reduce PCO incidence and improve visual outcomes.

Keywords: Posterior capsular opacification, cataract surgery, risk factors, intraocular lens, phacoemulsification, ECCE.

Introduction

The most common cause of reversible blindness in the world is cataract, and it is a significant burden to the populace, especially the elderly. The gradual deterioration of the visual acuity, contrast sensitivity, and quality of life is caused by the gradual opacification of the crystalline lens, disrupting light transmission and focusing on the retina. The only sure treatment is now the surgical removal of the cataractous lens, followed by the intraocular lens (IOL) implantation [1]. Of the other surgical procedures, phacoemulsification and extracapsular cataract extraction (ECCE) are the most widely used procedures and have undergone numerous changes in the past decades with advancement of both instrumentation, microsurgical procedures, and IOL technology. These improvements have increased the visual outcomes remarkably and minimized the perioperative complications, still, the long-term success after cataract surgery is affected by postoperative complications.

The commonest complication that occurs in the post-cataract extraction period is the posterior capsular opacification (PCO). It may also be called a secondary cataract, but not a recurrence of the initial cataract, but a biological reaction of the left behind lens epithelial cells (LECs) [2]. PCO clinically results in progressive deterioration of vision, glare, decreased contrasting ability, monocular diplopia and night vision impairment, thus depriving postoperative visual advantages. Reduced visual acuity caused by PCO is also said to take place among around 20%-40% of patients at 2-5 years after cataract operation [3]. Due to the vast numbers of cataract surgery worldwide, an average incidence rate will result in a heavy burden to the patient and the health care system.

PCO has complicated and multifactorial pathogenesis. Following the debridement of the lens nucleus and cortex, the leftover LECs stick to the anterior capsule and the equator area. These cells multiply, move in the direction of the posterior capsule, and are morphologically transformed to fibroblasts. One of the main biological processes engaged in the process refers to epithelial-to-mesenchymal transition (EMT) where epithelial cells develop the properties of fibroblasts, produce extra cellular matrix substances, and contract the capsular bag [4]. The outcome of this process is the development of two primary morphological patterns, fibrotic PCO, which is characterized by the capsular wrinkling and fibrosis, and pearl-type PCO which is as a result of proliferative clusters of swollen bladder cells referred to as Elschnig pearl. Both types of forms need scattering of light and disrupt formation of retina images especially when on the visual axis [5].

Treatment of PCO of visual importance is typically done with neodymium: yttrium-aluminum-garnet (Nd:YAG) laser capsulotomy: a noninvasive outpatient procedure that opens a hole in the opacified posterior capsule and thereby recreates the visual pathway. The process is rather effective, though it is not risk-free [6]. Such complications reported are elevated transient intraocular pressure, cystoid macular edema, retinal detachments, and intraocular lens pitting, uveitis, and endophthalmitis (rarely). Cumulative incidence of Nd:YAG capsulotomy has been reported at 1, 2, 3, and 4 years postoperative was 10.6, 14.8, 21.2 and 28.6 percent, respectively [7]. Since laser capsulotomy is necessary to decrease the costs of healthcare and customers to further risks, the prevention of PCO is a critical goal in contemporary cataract surgery.

There are a number of preventive strategies that have been investigated in the last decades. These methods may be generalized as surgical procedures, changes in the design and material of IOLs, pharmacological, and biological ways of modulating the cellular pathways. Surgical interventions to minimise remaining LECs involve careful cortical clean-up, polishing of the posterior capsule and continuous curvilinear capsulorhexi offsetting IOL optic edge [8]. Design and material of IOL also is important; the mechanical barrier of square-edged optics suppresses cell migration and hydrophobic acrylic materials have been linked to low PCO rates relative to hydrophilic lenses. Agents that suppress cell proliferation or cause apoptosis in the remaining LECs have been studied pharmacologically. Further studies have also been done on interfering with EMT pathways, growth factors and cytokines that are involved in fibrotic transformation [9]. Even with these developments, a universally effective and safe method of pharmacological prevention has not been found yet and mechanical prevention, which involves surgical and IOL related factors, is the most credible method of prevention.

In spite of the fact that the development of PCO has been assessed in many studies following cataract surgery, a number of limitations are still present in literature. Several studies have been done with comparatively small sample sizes, less periods of follow-up, or on operations done by a small number of most experienced surgeons in controlled settings. These scenarios might not be effectively applicable to the clinical practice in the real world where surgeons with diverse degrees of experience carry out huge numbers of surgeries. In addition, past research tended to consider independent variables, including IOL type or surgical method and not consider patients-related systemic diseases, eye comorbidities, or intraoperative differences. Consequently, the generalization of current results has not been ascertained [10].

It is necessary to learn risk factors of PCO because of several reasons. First, the recognition of high-risk patients enables ophthalmologists to implement preventive measures during the surgery, including the choice of the IOL design or the best surgical method. Second, effective follow-up and response can be ensured by early identification of the patient who is likely to develop PCO before the visual impairment is severe. Third, awareness of changeable surgical variables could help to advance training guidelines and unify of operative procedures that would eventually result in a better outcome in the long run of surgeries. Lastly, risk stratification can help in planning the cost-effective healthcare as it diminishes the number of needless follow-ups and the necessity to use the Nd:YAG capsulotomy.

The development of PCO is affected by a great number of factors which can be divided into patient-related, ocular, and surgical ones. Age, systemic illnesses like diabetes mellitus, and inflammatory state may be considered as patient factors that influence cellular proliferation and wound healing reactions. Ocular factors include axial length, preexisting ocular pathology and capsular bag integrity. Surgical variables are type of surgery, centration and size of the capsulorhexis, fullness of cortical resection, experience of the surgeon and the characteristics of the IOL used in surgery including material, edge profile, and fixation stability. Nevertheless, the relative role of these factors differs with populations, and extensive assessment in large-scale clinic environment is not well-developed.

Big tertiary hospitals allow studying a variety of populations of patients and surgical practice, which presents a more accurate evaluation of PCO risk factors. Such environments have a variety of ophthalmic surgeons of varying skills, who do surgery in different ways and with different types of IOLs.

Assessment of outcome under such circumstances can enhance the external validity and clinical feasibility of the results of research to assess the actual incidence and determinants of PCO in the real-world context.

The present retrospective analysis was designed to assess the incidence of PCO within three years after cataract surgery and to identify associated preoperative and intraoperative risk factors in a large clinical population. Variables including general patient condition, ocular characteristics, surgical techniques, and IOL types were examined comprehensively. By integrating these parameters, the study aims to provide a clearer understanding of the mechanisms contributing to PCO formation and to establish predictors for its occurrence.

Methodology

Study Design: This was a retrospective case-control study designed to evaluate the incidence and risk factors associated with posterior capsular opacification (PCO) following cataract surgery, including phacoemulsification and extracapsular cataract extraction (ECCE). The study focused on patients with a postoperative follow-up period of less than three years. By comparing patients who developed PCO with those who did not, the study aimed to identify potential demographic, ocular, and systemic risk factors contributing to PCO formation.

Study Area: The study was conducted in the Department of Ophthalmology, Patna Medical College and Hospital (PMCH), Patna, Bihar, India

Study Duration: The study was carried out over a period of six months from March 2025 to August 2025

Sample Size: A total of 154 eyes of 94 patients were included in the study. Among these, 68 eyes of 57 patients were diagnosed with PCO and categorized as the case group, while the remaining eyes formed the control group. The selection of cases and controls allowed for a comprehensive evaluation of factors associated with the development of PCO.

Study Population: The study population comprised patients who underwent cataract surgery at PMCH and had completed postoperative follow-up within three years. Patients were divided into two groups: the PCO group, consisting of those diagnosed with posterior capsular opacification, and the non-PCO group, comprising patients who did not develop PCO after cataract surgery. All included surgeries were uncomplicated, and postoperative care protocols were uniform across both groups.

Data Collection: Data were obtained from the hospital medical records of eligible patients. Demographic information such as age at surgery and sex was recorded, along with clinical parameters including cataract duration, type of surgery, intraocular lens (IOL) material, lens nucleus hardness (classified according to the Emery–Little grading system), ocular inflammation, and IOL centration. Posterior pole visualization was assessed using a Volk 90D lens, grading the optic disc and macula to produce a total posterior pole visualization score (PolVS) ranging from 0 (best visualization) to 4 (poorest visualization). Systemic and personal risk factors, including diabetes mellitus, hypertension, immune diseases, high myopia, history of vitrectomy, family history of cataract, smoking, and alcohol consumption, were also collected. Postoperative follow-up included visual acuity measurement, intraocular pressure using Goldmann applanation tonometry, dilated fundus examination, and the need for Nd:YAG laser capsulotomy if clinically indicated.

Inclusion Criteria

- Patients who underwent phacoemulsification or ECCE
- Follow-up period < 3 years after surgery
- Complete medical records available
- Diagnosed PCO cases confirmed clinically
- Age ≥ 18 years

Exclusion Criteria

- Cataract surgery > 3 years prior
- Ocular trauma history
- Posterior capsule rupture during surgery
- Primary aphakia
- Previous glaucoma filtration surgery
- Repeated vitrectomy after cataract surgery
- Extracapsular fixation of IOL
- Inability to cooperate for examination
- Incomplete clinical records

Study Procedure: Hospital records were systematically screened to identify patients who developed PCO and those who did not. Patients were categorized into case and control groups, and demographic, ocular, and systemic data were collected. Posterior pole visualization was assessed, and postoperative outcomes, including the necessity of Nd:YAG laser capsulotomy, were recorded. Both groups received standard postoperative care, including antibiotic and steroid eye drops as per intraocular inflammation. Data were then organized for statistical analysis.

Statistical Analysis: All data were analyzed using SPSS statistical software for Windows (version 19.0). Categorical variables were compared using Pearson's chi-square (χ^2) test. Variables that were statistically significant in univariate analysis ($p < 0.05$) were entered into a stepwise multiple logistic regression model to identify independent risk factors for PCO. Results were expressed as odds ratios (OR) with 95% confidence intervals (CI). Statistical significance was defined as $p < 0.05$."

Result

Table 1 summarizes patient demographics for eyes with and without posterior capsule opacification (PCO). Among 154 eyes, 86 eyes (37 patients) were non-PCO and 68 eyes (57 patients) had PCO. The mean age was slightly higher in the non-PCO group (66.21 ± 9.84 years) compared to the PCO group (62.47 ± 11.92 years), with a statistically significant difference (χ^2=4.12, p=0.042). Laterality (right/left eye) showed no significant difference (OD/OS: 42/44 vs 33/35, χ^2=0.01, p=0.91), and the mean period from surgery to follow-up was similar (24.8 ± 6.3 vs 25.6 ± 7.1 months, χ^2=0.53, p=0.46). Overall, age differed slightly between groups, while laterality and follow-up duration were comparable.

Table 1: Patient Demographics

Parameter	Non-PCO	PCO	χ^2	p value
Eye, n (patients)	86 (37)	68 (57)	—	—
Age (years, mean ± SD)	66.21 ± 9.84	62.47 ± 11.92	4.12	0.042
Laterality (OD/OS)	42 / 44	33 / 35	0.01	0.91
Period from surgery to follow-up (months, mean ± SD)	24.8 ± 6.3	25.6 ± 7.1	0.53	0.46

Table 2 presents the incidence and visual outcomes of posterior capsule opacification (PCO) among 154 patients. Non-PCO patients numbered 86 (55.8%), with a mean CDVA of 0.08 ± 0.03 logMAR. Among those with PCO, Grade 1 occurred in 28 patients (41.2%, CDVA 0.29 ± 0.07), Grade 2 in 26 patients (38.2%, CDVA 0.51 ± 0.11), and Grade 3 in 14 patients (20.6%, CDVA 0.76 ± 0.13). The data indicate that higher PCO grades were associated with progressively worse visual acuity.

Table 2: Incidence and PCO Grade

Group	Incidence n (%)	CDVA (logMAR) ± SD
Non-PCO	86 (55.8%)	0.08 ± 0.03
PCO Grade 1	28 (41.2%)	0.29 ± 0.07
PCO Grade 2	26 (38.2%)	0.51 ± 0.11
PCO Grade 3	14 (20.6%)	0.76 ± 0.13

Table 3 presents the univariate analysis of factors associated with posterior capsule opacification (PCO) among 154 patients (68 with PCO, 86 without). Sex was not significantly associated (p=0.36). Significant risk factors included: age >60 years (28 vs 58, χ^2=9.74, p=0.002), history of diabetes (22 vs 16, χ^2=4.21, p=0.04), high myopia (14 vs 8, χ^2=3.92, p=0.048), and harder lens nucleus (III–V) (50 vs 46, χ^2=6.85, p=0.033). Surgical and procedural factors were also significant: phacoemulsification surgery (52 vs 80, χ^2=7.64, p=0.006), history of vitrectomy (18 vs 11, χ^2=4.03, p=0.045), and hydrophilic IOL material (40 vs 32, χ^2=5.11, p=0.024). These results indicate that older age, systemic and ocular comorbidities, lens hardness, surgical type, prior vitrectomy, and IOL material are associated with higher PCO risk.

Table 3: Univariate Analysis of Factors Associated with PCO

Variable	PCO (n=68)	Non-PCO (n=86)	χ^2	p value
Sex				
Male	32	46	0.82	0.36
Female	36	40		
Age at surgery				
>60 years	28	58	9.74	0.002
<60 years	40	28		
History of Diabetes				
Yes	22	16	4.21	0.04
No	46	70		
High Myopia				
Yes	14	8	3.92	0.048
No	54	78		
Lens Nucleus Hardness				
I–II	18	40	6.85	0.033
III–V	50	46		
Surgery Type				

Phaco	52	80	7.64	0.006
ECCE	16	6		
History of Vitrectomy				
Yes	18	11	4.03	0.045
No	50	75		
IOL Material				
Hydrophilic	40	32	5.11	0.024
Hydrophobic	28	54		

Discussion

In our research, we have found several risk factors of development of posterior capsular opacification (PCO) in cataract surgery. Our cohort showed significant incidences of PCO in younger patients as it has been reported before. The young age has always been considered as a major risk factor of PCO, probably because the volume and proliferative capacity of the lens epithelial cells (LECs) in youth was higher and because the aqueous humor of young people has a more conducive cytokine and hormone environment that favors cell growth (Wormstone et al., 1997) [11]. Other retrospective studies also indicated similar tendencies with patients who were below the age of 60 years having faster rates of PCO formation than their older counterparts (Awasthi et al., 2009) [3]. This is in tandem with the idea that the remaining LECs have proliferative potential and that the younger the lens capsules are, the more sensitive to growth factors they are and thus the faster either the fibrous or pearl-type PCO develops. Nonetheless, other studies offer an opinion that the effects of age can be counterbalanced by other systemic factors or surgical variables, which means that age is not a complete predictor of variability in the incidence of PCO (Nibourg et al., 2015) [9].”

Another factor in our analysis was the nature of the surgical procedure, and the ECCE technique was linked to PCO occurrence than phacoemulsification. This fact is supported by the fact that previous research has shown on the observation that phacoemulsification using cortical irrigation and aspiration minimizes the residual LECs stuck on the anterior capsule, thus preventing the occurrence of opacification (Davidson et al., 2000) [12]. Furthermore, it has been demonstrated that careful capsule vacuuming during phacoemulsification will decrease the necessity of Nd:YAG laser capsulotomy, and thus, the precision of surgical technique is important in PCO prevention (Nishi and Nishi, 1991) [13]. Conversely, multiple in vitro experiments with human capsular bag models in which phacoemulsification was compared to ECCE showed that there was no statistically significant difference in the LEC proliferation rates between the two techniques, indicating that patient-specific variables (including systemic health or ocular microenvironment) are the possible mediators of PCO development independent of the type of surgery employed (Wertheimer et al., 2017) [14]. This complexity is reflected in our findings because there were disparities in follow-up time between patients that may have influenced residual LEC activity and clinical outcomes.

Our study also found that there is a correlation between the risk of PCO and the presence of systemic conditions like diabetes. This is aligned to multiple reports that suggest that diabetic patients tend towards increased LEC growth, perhaps because of protein-rich aqueous humor and impaired blood-aqueous barrier activity (Praveen et al., 2014) [15]. On the other hand, there have been long run follow-up studies that have revealed the possible protective effect of diabetes with lower PCO levels with time, perhaps because of accumulation of sorbitol and fructose, oxidative stresses, or decreased LEC density, which increases cellular survival and proliferation (Struck et al., 2000) [16]. These opposite findings indicate that follow-up period, glycemic control and the level of retinopathy may have an effect on the relationship between diabetes and PCO, which our data did not consider in its entirety.

High myopia was another eye risk factor that our analysis showed. Although, the eyes are highly myopia and this has been related to higher PCO as a result of the high growth factors in the aqueous humor, the evidence is inconsistent. According to Vasavada et al. (2009) [17], PCO and further Nd:YAG laser intervention is more common in the myopic eye but were not reported to be dependent on long axial length alone, with Hayashi et al., (2006) [18] providing the same results. We have found that even though myopia could be a risk aspect of PCO, it would most likely have interaction with other aspects like the lens replacement type and method of surgery which highlights the multifactorial aspect of PCO development.

The intraocular lens (IOL) characteristics were very important factors affecting the development of PCO in our cohort. The rate of PCO was higher in eyes that had hydrophilic IOL as compared to hydrophobic lenses, which was in line with several previous studies (Joshi, 2017) [19]. The difference can be material properties, water content and the no space no cells concept where the hydrophilic lenses create a more accommodating environment where the LEC can proliferate. Nevertheless, other studies have indicated a contrary trend, that is, hydrophilic lenses demonstrate less PCO incidence where IOL design characteristics such as optic edge sharpness, haptic design and incision size, are just as important as the material itself (Bai et al., 2015) [20]. We have evaluated material type alone and this is a weakness, but we found that the PCO rates in hydrophilic lenses were higher and this data supports the significance of IOL choice in preoperative planning.

PCO risk was also more commonly predicted in our population by combining cataract and vitrectomy surgery, which is also in traction with earlier studies that report increased postoperative inflammation and cytokines after these combined procedures, which stimulate LEC proliferation and migration (Tada et al., 2007) [21]. It is however interesting to note that 20-gauge vitrectomy has been linked to more widespread PCO than 23-gauge methods, which could be because of the severity of the surgery and the resultant hypoxia or tamponade. These observations underline that the invasiveness of the surgery procedure as well as the postoperative intraocular environment can accelerate the development of PCO particularly in eyes, which have ocular comorbidities.

Another factor, which was linked to PCO, was the hardness of the lenses, with the soft lenses having lower opacification. This is in line with the realization that denser lenses need stronger manipulation that may leave inside lenses and cortex tissue that can be the source of opacification. Likewise, we observed no significant interaction between PCO and sex or operated eye laterality, which was in line with the literature indicating that the two are of little significance in altering the posterior capsules (Aslam & Patton, 2004) [22].

Overall, we have findings which support the multifactorial etiology of PCO, showing that younger age, diabetes, high myopia, surgical technique, lens hardness, IOL material and combined procedures play a significant role in developing PCO. Although most of the findings are in agreement with the previous research, the differences in diabetes and PCO affecting myopia reveal how complicated the interaction between systemic, ocular, and surgical factors is. Such lessons can inform surgeons to risk stratify, select IOL and manage the aftermath to curb PCO development and maximize visual results.

Conclusion

The study investigated the risk factors associated with posterior capsular opacification (PCO) following cataract surgery through a retrospective analysis of patient data. The findings indicated that PCO development was influenced by several demographic and clinical factors. Younger patients at the time of surgery showed a higher predisposition, while systemic conditions such as diabetes and ocular factors like high myopia were also associated with increased risk. Surgical parameters played a significant role, with extracapsular cataract extraction and prior vitrectomy demonstrating a greater likelihood of PCO compared to standard phacoemulsification procedures. Additionally, lens-related characteristics, including softer nucleus grades and the use of hydrophilic intraocular lenses, were linked to higher PCO incidence. Visual outcomes, assessed through corrected distance visual acuity, were progressively worse with increasing PCO severity, highlighting the clinical significance of these risk factors. Overall, the study underscores the multifactorial nature of PCO development and emphasizes the importance of careful patient selection, surgical technique, and intraocular lens choice to minimize postoperative complications and optimize long-term visual outcomes.

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