Chang et al. BMC Ophthalmology (2025) 25:188
https://doi.org/10.1186/s12886-025-03983-3

BMC Ophthalmology

RESEARCH

Open Access

Influencing factors and prediction model construction of posterior capsular opacification after intraocular lens implantation treated with Nd: YAG laser

Hongmei Chang[1*], Qiang Fang[2] and Xianli Liu[1]

Abstract

Objective To explore the influencing factors of posterior capsular opacification (Posterior Capsular Opacification, PCO) after intraocular lens implantation treated with Nd: YAG(Neodymium: Yttrium-Aluminum-Garnet) laser and to establish a predictive model to evaluate its risk.

Methods From January 2018 to June 2023, the data of 312 patients with posterior capsule opacification and Nd: YAG laser treatment in our hospital were retrospectively analyzed. All patients were randomly divided into training group (218 cases) and verification group (94 cases) at the ratio of 7:3. In the training set, the independent risk factors of posterior capsule opacification before operation were identified by multivariate Logistic regression analysis, and the nomogram prediction model was constructed. By drawing ROC (receiver operating characteristic) curve and calibration curve, the prediction effectiveness of the model is evaluated, and the verification is carried out in the verification set, and its clinical application value is explored by Decision Curve Analysis (DCA).

Results Among 312 patients, 84 (22.92%) developed PCO. The logistic results showed that age ≥ 60 years, extracapsular excision surgery, multifocal intraocular lens, axial length ≥ 24 mm, preoperative visual acuity < 0.3, high laser energy, and large posterior capsule incision aperture were associated with the occurrence of PCO ($P < 0.05$). The C-index indexes of the nomograph model were 0.870 and 0.842 in the training set and verification set, respectively, and the average was absolute. In the Hosmer-Lemeshow test, the χ^2 values of the training set and the verification set are 4.007($P = 0.856$) and 2.841($P = 0.943$), respectively. The ROC curve shows that the AUC(Area Under Curve) values of the training set and the verification set are 0.870 (95% CI: 0.810–0.929) and 0.843 (95% CI: 0.732–0.954) respectively, and the combination of sensitivity and specificity is 0.792, 0.810, 0.765 and 0.792 respectively.

Conclusion The nomogram prediction model based on Nd: YAG laser treatment of PCO risk factors after intraocular lens implantation has high accuracy and calibration, which can provide a key reference for formulating preventive measures, help to reduce the incidence of PCO and improve the prognosis of patients.

*Correspondence:
Hongmei Chang
hongmeidoc@163.com

Full list of author information is available at the end of the article

Keywords Nd:YAG laser, Intraocular lens implantation, Posterior capsule opacities, Influencing factors, Prediction model

Introduction

PCO (Posterior Capsular Opacification) is a key factor in the recurrence of visual impairment after intraocular lens implantation, which is related to the proliferation and migration of residual lens epithelial cells, seriously affecting the visual quality and quality of life of patients, and increasing medical burden [1]. Nd: YAG laser posterior capsulotomy is widely used in clinical practice due to its simple operation, minimal eye damage, and fast recovery. However, the treatment effects vary greatly among different patients, with some showing significant improvement in vision, while others may experience complications or poor improvement in vision [2]. At present, although scholars at home and abroad have studied the influencing factors of Nd: YAG laser treatment for PCO, the results are inconsistent and there is no consensus yet [3]. Previous studies have involved factors such as individual patients, eye structure, surgery, and postoperative inflammation, but the weights and interrelationships of each factor are not clear. Most analyses are based on single or few factors, and there is a lack of comprehensive predictive models constructed from multiple factors, making it difficult to comprehensively evaluate patients' response to laser therapy [4]. Based on this, this study retrospectively analyzed the clinical data of patients with PCO treated with Nd: YAG laser, systematically explored the factors that affect the treatment effect, and used multi factor analysis to construct a predictive model, aiming to provide scientific basis for clinical doctors to evaluate patient prognosis, achieve personalized treatment, improve treatment effectiveness, optimize patient visual function and quality of life [5].

Objects and methods

Subjects

We retrospectively analyzed the detailed clinical records of 312 patients who underwent intraocular lens implantation and developed posterior capsule opacities after surgery and received Nd: YAG laser treatment in our hospital from January 2018 to June 2023. Inclusion criteria: ① PCO; after intraocular lens implantation was definitely diagnosed; ② Nd: YAG laser treatment; ③ The patient's medical records, examination data, and laser treatment records are intact; ④ Sign informed consent form. Exclusion criteria: ① Patients with severe ocular diseases or complications, such as retinal detachment and macular degeneration; ② Patients with serious complications after intraocular lens implantation, such as intraocular lens dislocation and endophthalmitis; ③ Patients with contraindication to Nd: YAG laser treatment. To minimize selection bias, this study used a completely randomized grouping method supplemented by a stratified randomization strategy. The specific steps are as follows: Firstly, stratify the patients based on their baseline characteristics (such as age, gender, surgical approach, type of artificial lens, etc.); Then, a random number table method is used for random grouping within each layer to ensure that the baseline characteristics of patients within each group are as consistent as possible. Finally, all cases were divided into a training set (218 cases) and a validation set (94 cases) in a 7:3 ratio. This study has been approved by the Ethics Committee of Zibo Hospital (Ethics Approval Number: ZMH-2018022215). However, due to the comprehensive upgrade and migration of hospital information systems, this process involves a large amount of data conversion and integration. Due to technical malfunctions, some historical research materials were lost during data conversion, including the original ethical report of this study. Therefore, we are currently unable to provide an ethical report. We are responsible for the ethical compliance during the research process.

Nd: YAG laser treatment

In patients with postoperative PCO, a posterior capsulotomy procedure was performed using Nd: YAG laser technology. Prior to treatment, we ensured that the patient's pupils were sufficiently dilated to 7–8 mm to adequately expose the posterior capsular opacification area for laser treatment. During the laser treatment process, the Allegretto Wave Eye-Q Nd: YAG laser therapy device (model: Allegretto Wave Eye-Q, Origin: Germany) The laser energy is precisely set to 1-2 mJ, and 2–3 pulses are emitted for each treatment. The specific number of pulses is fine tuned according to the severity and range of posterior capsule opacity. If the turbid area is large or the degree of turbidity is severe, the number of pulses can be appropriately increased, but the total energy per treatment does not exceed 10 mJ, but sometimes in order to achieve a sufficiently large incision aperture to meet treatment needs, the total energy may also be appropriately exceeded according to the actual situation, but it needs to be strictly controlled within a safe range. In a very small number of complex cases, such as extensive posterior capsule opacity or significant tissue thickening, higher total energy (up to 300 mJ) may be required to perform effective posterior capsulotomy. This high-energy use is carried out under strict monitoring to ensure that the surrounding eye tissue is not damaged, and the patient's eye reactions are closely observed after surgery. Ofloxacin eye drops were used once an hour immediately after treatment, and changed to 4 times a day for 3 days after 6 h. For postoperative inflammatory reaction, after evaluating the patient's individual situation, decide whether to use dexamethasone eye drops. If the patient has obvious signs of inflammation, such as eye pain, jealousy and decreased vision, and other reasons are excluded, dexamethasone eye drops can be used 6 times a day, and the amount is reduced according to the inflammation for 1–2 weeks; If there is no inflammation or slight inflammation, only closely observe the eye condition, and do not use dexamethasone eye drops for the time being. The intraocular pressure was measured at 1 h, 2 h, 4 h, 8 h and every day after cataract surgery, and the increase of intraocular pressure was treated according to the principle of cataract surgery. The patient wears sunglasses to avoid abnormality, and the effect and treatment problems are reviewed one week after operation.

Data collection

Patients' general data (age, gender, Body Mass Index (BMI)), diabetes mellitus, hypertension, cardiovascular disease, history of ocular inflammation, history of ocular trauma and habit of using eyes) and operation-related data (operation method, intraocular lens type, intraocular lens material, operation time, laser energy, pulses, and posterior capsulotomy aperture) were collected, together with preoperative eye examination data (vision, intraocular pressure, axial length of the eye, anterior chamber depth, and macular thickness) and postoperative related data (type of antibiotics used, duration of glucocorticoid use, vision one week after surgery, and whether there were postoperative complications).

Efficacy evaluation

After one year of laser treatment, measure vision using a standard visual acuity chart (such as the Snellen scale) in a dark room. Firstly, check the uncorrected visual acuity, and then determine the optimal corrected visual acuity through comprehensive optometry. Repeat the measurement three times to obtain the average value. Judging the effectiveness of treatment based on the fact that the best corrected visual acuity has improved by two or more lines compared to before treatment, and recording and evaluating the therapeutic effect in detail. In the subsequent follow-up, the above vision measurement methods were also used for the 18 month postoperative follow-up. Record in detail the uncorrected visual acuity and best corrected visual acuity data measured each time, and observe the dynamic changes in visual acuity. In addition to visual acuity measurement, the recurrence of posterior capsule opacity and the occurrence of ocular complications are also included in the efficacy evaluation indicators. During each follow-up, professional ophthalmic examination equipment is used to carefully observe for signs of recurrent posterior capsule opacities, and detailed information such as the number and recurrence time of patients with recurrent posterior capsule opacities is recorded. At the same time, closely monitor patients for any ocular complications such as abnormally elevated intraocular pressure, retinal damage, intraocular inflammation, etc. Record the specific type, time, and severity of complications.

Statistical methods

SPSS 26.0 statistical software was used to process and analyze the data. When the measurement data conforms to a normal distribution, it is represented by $\overline{x} \pm \mathrm{s}$, and independent sample t-test is used for comparison between two groups; When it does not conform to a normal distribution, M (Q1, Q3) is used to represent it, and Mann Whitney U test is used for inter group comparison. The comparison of count data is conducted using the chi square test or Fisher's exact probability method. Multiple logistic regression analysis was used to screen for risk factors that affect treatment efficacy, with $P<0.05$ indicating statistically significant differences. Use the R software "rms" package to establish a column chart model, use the "pROC" package to draw the Receiver Operating Characteristic (ROC) curve of the subjects to analyze the predictive value of the model, use the Bootstrap method to internally validate the model, and draw a calibration curve between the predicted results and the actual results. Calculate the Concordance Index (C-index) of the model, and evaluate the goodness of fit of the prediction model using the Hosmer Lemeshow test. DCA (Decision Curve Analysis) evaluates the clinical application value of the decision curve analysis model.

Results

Comparison of PCO incidence and clinical features between the training set and the verification set

Among the 218 patients in the training set, 65 (29.82%) and 19 (20.21%) of the 94 patients in the verification set experienced PCO. No statistically significant difference in the incidence and clinical characteristics of PCO between the training set and the verification set was observed ($P>0.05$), as shown in Table 1.

Training set PCO risk factor analysis

Univariate analysis of the training set showed that there were significant differences in age, surgical method, intraocular lens type, axial length, preoperative vision, laser energy, and posterior capsulotomy aperture between PCO patients and PCO-free patients ($P<0.05$), as shown in Table 2. The occurrence of PCO was taken as the dependent variable (0 = none, 1 = Yes) and the factors (age, surgical method, intraocular lens type, axial length, preoperative vision, laser energy, and posterior

Table 1 Comparison of clinical characteristics between training set and verification set ($\overline{x} \pm s$)

Index		Training set (*n* = 218)	Validation set (*n* = 94)	t/χ²	*P*
Age (years)	<60	122(55.96)	62(65.96)	2.711	0.099
	≥60	96(44.04)	32(34.04)		
BMI(kg/m2)		22.15 ± 3.24	22.37 ± 3.55	0.534	0.593
gender	man	120(55.00)	52(55.32)	0.002	0.964
	woman	98(45.00)	42(44.68)		
diabetes	be	32(14.68)	14(14.89)	0.002	0.960
	no	186(85.32)	80(85.11)		
hypertension	be	45(20.64)	20(21.28)	0.016	0.899
	no	173(79.63)	74(78.72)		
Cardiovascular disease	be	28(12.84)	15(15.96)	0.535	0.464
	no	190(87.16)	79(84.04)		
History of ocular inflammation	be	22(10.09)	8(8.51)	0.188	0.663
	no	196(89.91)	86(91.49)		
History of ocular trauma	be	15(6.88)	6(6.38)	0.025	0.872
	no	203(93.12)	88(93.62)		
Surgical approach	Ultrasonic emulsification	185(84.86)	81(86.17)	0.089	0.764
	Extracapsular extraction	33(15.14)	13(13.83)		
Intraocular lens type	Single focus	161(73.85)	68(72.34)	0.077	0.781
	Multifocal	57(26.15)	26(27.66)		
Intraocular lens material	Hydrophobic material	135(62.39)	58(61.70)	0.001	0.970
	Hydrophilic material	83(37.61)	36(38.30)		
Type of antibiotics use	Single antibiotic	105(48.17)	45(47.87)	0.002	0.961
	Combined antibiotics	113(51.83)	49(52.13)		
Duration of glucocorticoid use	< 1 week	75(34.40)	32(34.04)	0.016	0.991
	1–2 weeks	98(44.95)	42(44.68)		
	> 2 weeks	45(20.64)	20(21.28)		
Eye axis length (mm)	<24	170(77.98)	72(76.60)	0.072	0.787
	≥ 24	48(22.02)	22(23.40)		
Anterior chamber depth (mm)		3.21 ± 0.57	3.25 ± 0.53	0.580	0.561
Operation time (min)		35.27 ± 10.47	37.64 ± 10.03	1.857	0.064
Laser energy (mj)		2.21 ± 0.84	2.08 ± 0.91	1.222	0.222
Pulse number		85.37 ± 24.26	81.06 ± 24.37	1.437	0.151
Posterior capsulotomy aperture (mm)		3.57 ± 2.54	3.07 ± 2.44	1.614	0.107
Macular thickness (μm)		232.54 ± 35.47	229.54 ± 34.84	0.689	0.491
Preoperative vision	<0.3	45(20.64)	20(21.28)	0.077	0.962
	0.3 ~ 0.8	138(63.30)	58(61.70)		
	>0.8	35(16.06)	16(17.02)		
Intraocular pressure (mmHg)		15.24 ± 3.24	15.18 ± 3.85	0.141	0.887
Eye habit	Long time proximity	85(39.00)	38(40.43)	0.091	0.955
	normal	98(44.95)	42(44.68)		
	How outdoors	35(16.06)	14(14.89)		
Vision one year after surgery	<0.3	32(14.68)	14(14.89)	0.616	0.734
	0.3 ~ 0.8	124(56.88)	56(59.57)		
	>0.8	62(28.44)	34(36.17)		
Postoperative complications	be	51(23.39)	21(22.34)	0.041	0.839
	no	167(76.61)	73(77.66)		

Note: Due to the history of ocular inflammation and immune dysfunction in some patients, it is necessary to use quinolone eye drops (ofloxacin) and eye ointment (erythromycin) in combination to enhance the anti infective effect

capsulotomy aperture) with $P < 0.2$ in univariate analysis as the covariate for further multivariate Logistic regression analysis. The variable assignments are shown in Table 3. The results show that: Age, extracapsular extraction, multifocal intraocular lens, long axis length, preoperative vision < 0.3, high laser energy, and large posterior capsulotomy aperture were the independent risk factors for PCO ($P < 0.05$). In the regression model, the tolerance of each variable was > 0.1, the VIF was < 10, and the condition index was < 30. In addition, the

Table 2 Univariate analysis of PCO occurrence (x̄ s) $\overline{x} \pm s$)

Index		POC(*n* = 65)	No POC(*n* = 153)	t/χ^2	*P*
Age (years)	<60	25(38.46)	86(56.21)	3.324	0.001
	≥60	40(61.54)	57(37.25)		
BMI(kg/m2)		22.13 ± 3.87	22.45 ± 3.64	0.582	0.560
gender	man	37(56.92)	85(55.56)	0.034	0.852
	woman	28(43.08)	68(44.44)		
diabetes	be	12(18.46)	22(14.38)	0.577	0.447
	no	53(81.54)	131(85.62)		
hypertension	be	15(23.08)	30(19.61)	0.335	0.562
	no	50(76.92)	123(80.39)		
Cardiovascular disease	be	8(12.31)	18(11.76)	0.012	0.909
	no	57(87.69)	135(88.24)		
History of ocular inflammation	be	7(10.77)	15(9.80)	0.046	0.828
	no	58(89.23)	138(90.20)		
History of ocular trauma	be	5(7.69)	14(9.15)	0.121	0.727
	no	60(92.31)	139(90.85)		
Surgical approach	Ultrasonic emulsification	40(61.54)	122(79.74)	7.916	0.004
	Extracapsular extraction	25(38.46)	31(20.26)		
Intraocular lens type	Single focus	37(56.92)	115(75.16)	7.190	0.007
	Multifocal	28(43.08)	38(24.84)		
Intraocular lens material	Hydrophobic material	35(53.85)	85(55.56)	0.053	0.816
	Hydrophilic material	30(46.15)	68(44.44)		
Type of antibiotics use	Single antibiotic	40(61.54)	95(62.09)	0.005	0.938
	Combined antibiotics	25(38.46)	58(37.91)		
Duration of glucocorticoid use	< 1 week	22(33.85)	55(35.95)	0.128	0.937
	1–2 weeks	30(46.15)	70(45.75)		
	> 2 weeks	13(20.00)	28(18.30)		
Eye axis length (mm)	< 24	31(47.69)	100(65.26)	5.937	0.014
	≥ 24	34(52.31)	53(34.64)		
Anterior chamber depth (mm)		3.41 ± 0.78	3.34 ± 0.68	0.664	0.506
Operation time (min)		42.54 ± 15.23	40.98 ± 14.65	0.710	0.478
Laser energy (mj)		3.26 ± 1.24	2.78 ± 0.98	3.047	0.002
Pulse number		92.57 ± 28.45	88.67 ± 29.05	0.912	0.362
Posterior capsulotomy aperture (mm)		4.25 ± 1.03	3.83 ± 0.98	2.850	0.004
Macular thickness (μm)		264.35 ± 65.24	253.74 ± 62.43	1.132	0.258
Preoperative vision	<0.3	30(46.15)	45(29.41)	6.109	0.047
	0.3 ~ 0.8	28(43.08)	80(52.29)		
	>0.8	7(10.77)	28(18.30)		
Intraocular pressure (mmHg)		16.25 ± 4.59	15.59 ± 4.34	1.009	0.313
Eye habit	Long time proximity	32(49.23)	68(44.44)	1.055	0.590
	normal	25(38.46)	70(45.75)		
	How outdoors	8(12.31)	15(9.80)		
Vision one year after surgery	<0.3	21(32.31)	35(22.88)	2.142	0.342
	0.3 ~ 0.8	34(52.31)	90(58.82)		
	>0.8	10(15.38)	28(18.30)		
Postoperative complications	be	18(27.69)	31(20.26)	1.445	0.229
	no	47(72.31)	122(79.74)		

proportion of variances of multiple covariates without the same feature value was > 50%. Hence, there was no collinearity of each covariate, According to statistical analysis, the results showed no significant interaction effect between age and laser energy, indicating that in this study, their effects on the occurrence of PCO were relatively independent. At the same time, the collinearity issue between laser energy and cystotomy aperture was investigated, and through linear regression analysis, it was confirmed that there is no collinearity between the two, as shown in Table 4.

Table 3 Variable assignment method

Variable	Meaning	Evaluation
X1	age	<60 = 0, ≥ 60 = 1
X2	Surgical approach	Phacoemulsification = 0, extracapsular extraction = 1
X3	Intraocular lens type	Single focus = 0, multifocal = 1
X4	Eye axis length	< 24 = 0, ≥ 24 = 1
X5	Laser energy	continuous variable
X6	Posterior capsulotomy aperture	continuous variable
X7	Preoperative vision	<0.3 = 0, 0.3 ~ 0.8 = 1, >0.8 = 2
Y	Does PCO happen	None = 0, have = 1

Establishment of PCO nomogram prediction model

Based on the independent risk factors obtained from multivariate logistic regression analysis, we constructed a column chart prediction model using the 'rms' software package of R software. Firstly, the independent risk factors (age, surgical method, type of artificial lens, axial length, laser energy, posterior capsule incision aperture, preoperative visual acuity) were included in the model framework. Based on the regression coefficients obtained from multiple logistic regression analysis, assign corresponding weights to each factor, and then determine the score scale of each factor on the column chart. For example, age ≥ 60 years old is assigned a value of 1, corresponding to a certain score; The value of extracapsular excision surgery is 1, and there is also a corresponding score. Add up the scores corresponding to each factor of the patient to obtain the total score, which corresponds to the probability of PCO occurrence through the built-in function relationship of the model. See Figs. 1&2.

Assessment and validation of PCO nomogram prediction model

This study adopts a standard model development and validation process. Firstly, a column chart prediction model is constructed based on the training set data, and

Table 4 Multivariate logistic regression analysis of PCO

Index	B	Standard error	Wald	*P*	OR	95% confidence interval
Age	0.720	0.303	5.657	0.017	2.054	1.135 ~ 3.716
Surgical approach	0.900	0.325	7.682	0.006	2.460	1.302 ~ 4.648
Intraocular lens type	0.829	0.313	7.024	0.008	2.290	1.241 ~ 4.227
Eye axis length	0.727	0.301	5.842	0.016	2.069	1.147 ~ 3.732
Laser energy	0.420	0.144	8.509	0.004	1.521	1.148 ~ 2.017
Posterior capsulotomy aperture	0.439	0.159	7.675	0.006	1.551	1.137 ~ 2.117
Preoperative vision	-0.537	0.227	5.586	0.018	0.585	0.375 ~ 0.912

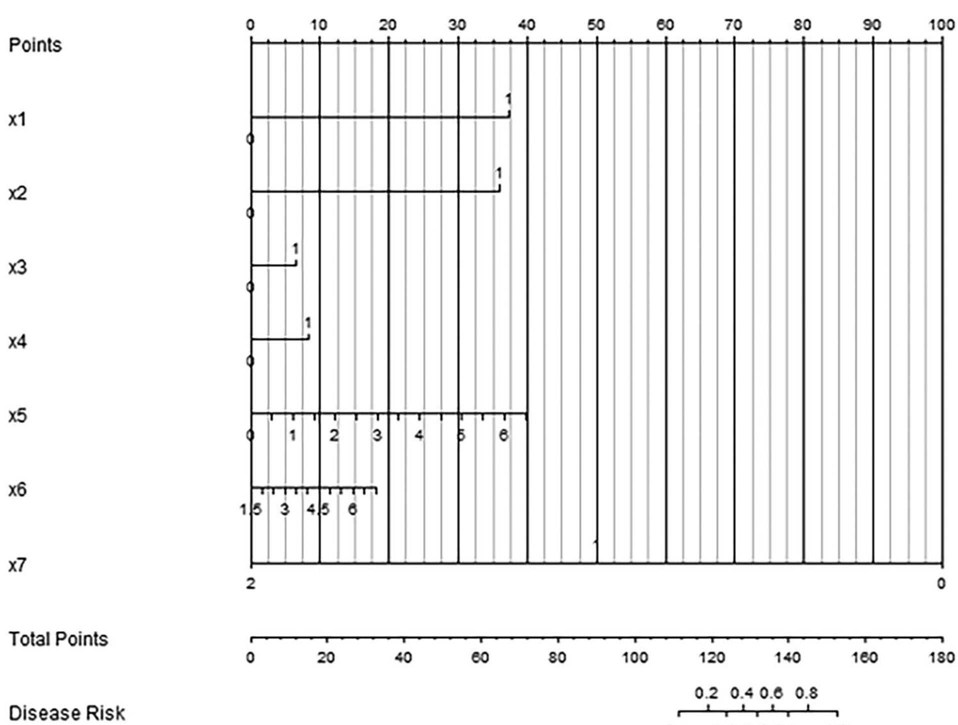

Fig. 1 PCO nomogram prediction model

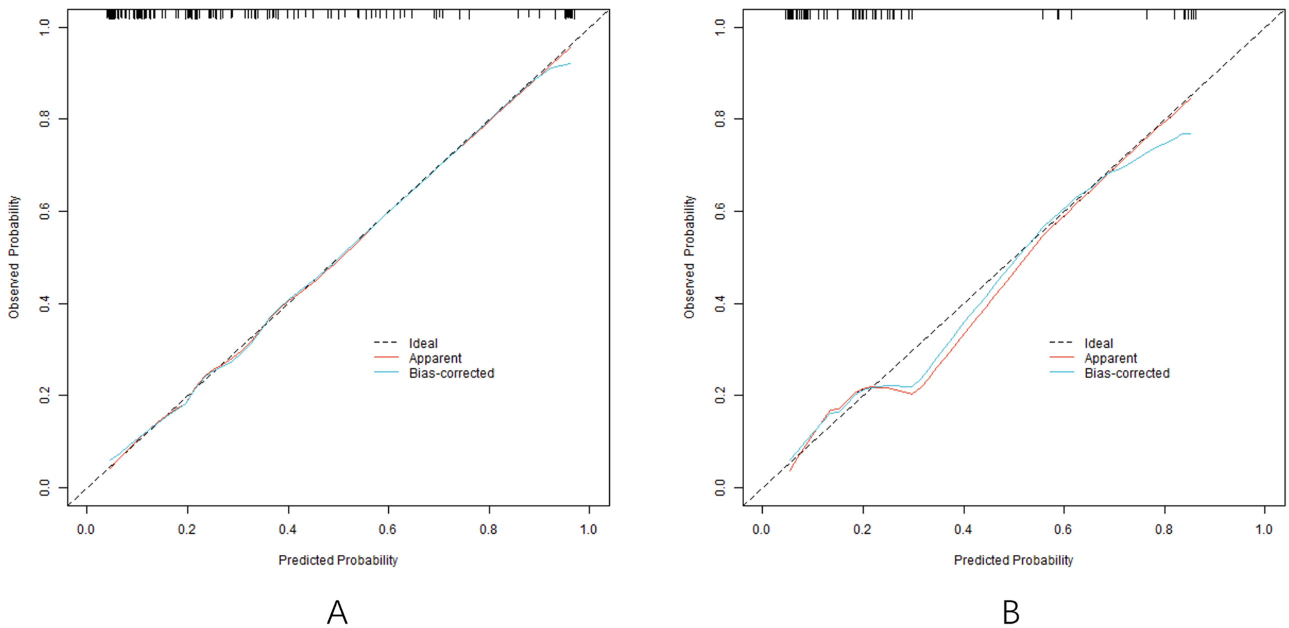

Fig. 2 Calibration curve (**A** is the training set, and **B** is the verification set)

each independent risk factor in the model is assigned corresponding scores according to the results of multivariate logistic regression analysis. Then, the fitting performance of the model on the training set is evaluated by drawing ROC curves, calibration curves, and decision curves. These curves demonstrate the predictive ability and calibration performance of the model on training data. Subsequently, the constructed model was applied to an independent validation set and its generalization ability was evaluated using the same evaluation methods (ROC curve, calibration curve, and decision curve). Among them, the C-index index index is used to measure the discriminative ability of the model, with a range of 0.5-1. The closer it is to 1, the stronger the model's ability to distinguish between patients with and without PCO. The C-index indices of the training set and validation set in this study were 0.870 and 0.842, respectively, indicating that the model has good discriminative ability. Further analysis of the calibration curve shows that there is good consistency between the predicted values of the model and the actual observed values. The mean absolute error (MAE) is used to quantify this degree of consistency, with MAEs of 0.063 and 0.073 for the training and validation sets, respectively. The smaller the value, the closer the predicted values of the model are to the actual values. The Hosmer Lemeshow test is used to evaluate the goodness of fit of the model. In this study, the chi square values of the training set and validation set were 4.007 ($P=0.856$) and 2.841 ($P=0.943$), respectively, with P values greater than 0.05, indicating that the model has a good fitting effect and can reflect the actual situation well. In addition, the area under the ROC curve (AUC) is used to evaluate the overall prediction accuracy of the model, and the closer the AUC is to 1, the higher the model accuracy. The AUC values of the training set and validation set are 0.870 (95% confidence interval: 0.810–0.929) and 0.843 (95% confidence interval: 0.732–0.954), respectively, with corresponding sensitivity and specificity combinations of 0.792 and 0.810, and 0.765 and 0.792, respectively, These results indicate that the model not only performs well on the training set, but also has good generalization ability on the independent validation set. respectively. See Fig. 3.

Analysis of decision curve of PCO nomogram prediction model

The decision curve showed that when the threshold probability was within the range of 0.05–0.95, the application of the nomogram model constructed in this study to predict PCO would have more clinical benefits than the preoperative decision that all PCOs were present or none were present. See Fig. 4.

Conclusion

PCO, a common complication after intraocular lens implantation, has significantly affected the visual quality of patients and the efficacy of the operation. With the continuous advancement of Nd: YAG laser technology, its application in the treatment of PCO is expanding day by day. The occurrence of PCO, however, remains somewhat unpredictable. In view of this, a detailed exploration and analysis of the relevant influencing factors of Nd: YAG laser treatment for PCO after intraocular lens implantation were conducted, and a risk prediction

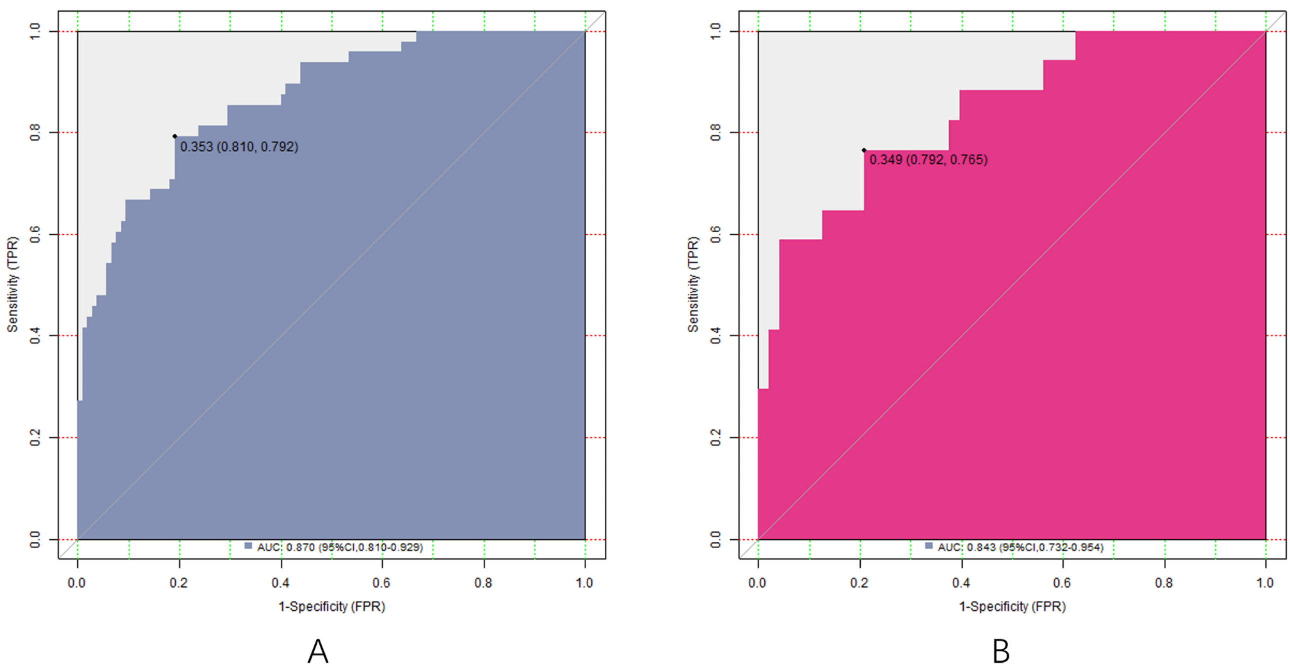

Fig. 3 ROC curve (**A** is the training set, and **B** is the verification set)

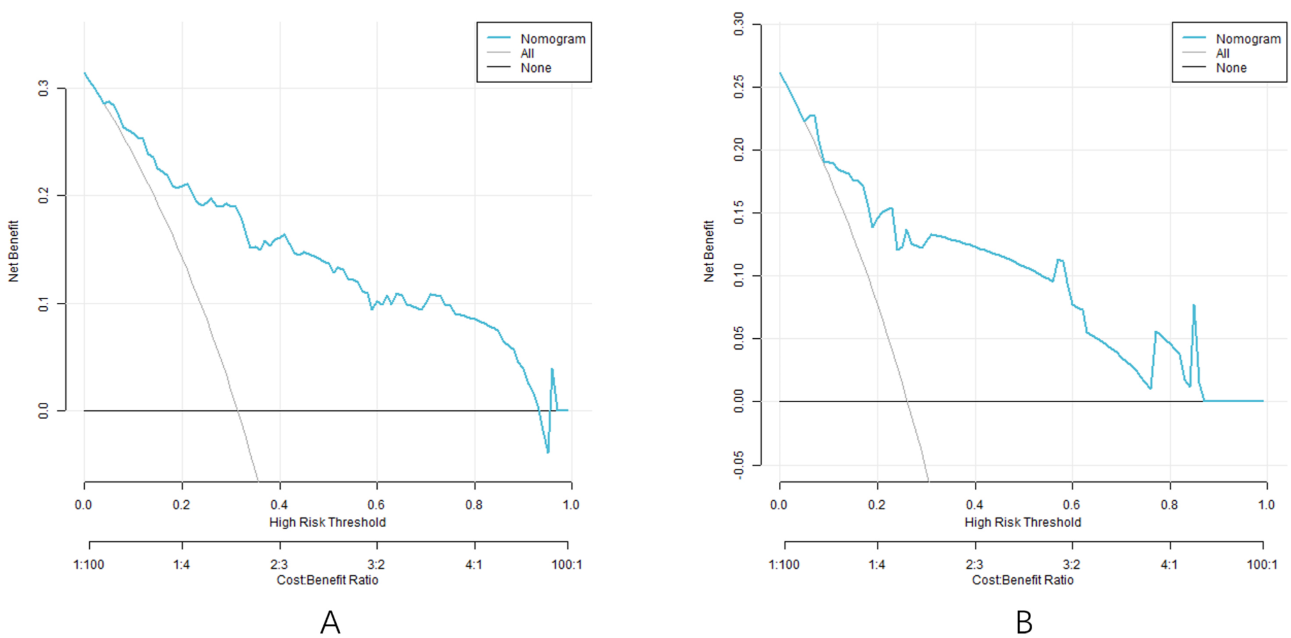

Fig. 4 Decision curve (**A** is the training set, and **B** is the verification set)

model was constructed based on this. For clinical practice, it has high predictive and generalization abilities.

First, age is an important factor in the pathogenesis of PCO. In detail, the proliferative activity and migration potential of lens epithelial cells gradually increase with age, resulting in an increased incidence of posterior capsule opacities. It may be related to the slow cell metabolism and weakened cell repair ability in the elderly [6]. Therefore, elderly patients should be more closely monitored for ocular conditions after surgery to detect and manage PCO in a timely manner. Second, extracapsular extraction is also a risk factor for PCO. Extracapsular extraction destroys the integrity of the lens capsular bag significantly, and it is easy to cause the lens epithelial cells to remain in the capsular bag, and then to proliferate and migrate, forming PCO [7]. In contrast, modern phacoemulsification has little damage to the integrity of the capsular bag and the incidence of PCO is relatively low. Therefore, when choosing the surgical approach, the specific conditions of patients should be fully considered and the surgical approach with less damage to the integrity of the capsular bag should be selected as far as possible [8]. Multifocal intraocular lens is also closely related to the occurrence of PCO. The design of multifocal intraocular lens is complex and the requirement for lens capsule is high. PCO may occur if the integrity of the capsular bag is damaged or the position of intraocular lens in the capsular bag is unstable [9]. Therefore, in the process of implementing multifocal intraocular lens implantation surgery, special attention should be paid to the precision of the surgical operation to ensure the stability of the intraocular lens position inside the capsule, thereby effectively reducing the probability of PCO occurrence. Axial length ≥ 24 mm is also an independent risk factor for PCO. Patients with axial length ≥ 24 mm may have certain abnormalities in the shape and size of the lens capsule, which can promote the proliferation and migration of lens epithelial cells [10]. In addition, patients with axial length ≥ 24 mm often have eye problems such as high myopia, which may further increase the potential risk of PCO. Therefore, for patients with an axial length ≥ 24 mm, postoperative monitoring of their eye condition should be conducted more closely to promptly detect and treat PCO [11]. Patients with preoperative vision < 0.3 also had a higher incidence of PCO. This may be related to our patient's poor ocular condition and the difficulty of surgery. For patients with poor preoperative vision, there are often a variety of ocular lesions, such as keratopathy and vitreous opacity, which may increase the risk of PCO [12]. Therefore, patients with poor preoperative vision should be fully evaluated and prepared before surgery, and the surgical protocol should be tailored to reduce the incidence of PCO. The high laser energy and large incision aperture of the posterior capsule have been confirmed in this study to be closely related to the occurrence of PCO and cannot be ignored as risk factors. Although PCO existed before receiving Nd: YAG laser treatment, if the laser energy is selected too high during the laser treatment process, it can cause thermal damage to the cyst. Thermal damage to the capsule can disrupt the original physiological environment of lens epithelial cells, disrupt the redox balance within the cells, activate a series of pro proliferative signaling pathways, and significantly accelerate the proliferation and migration activities of lens epithelial cells. These abnormally proliferating and migrating cells will gradually gather at the posterior capsule site, further exacerbating the degree of posterior capsule opacity. The larger incision aperture of the posterior capsule also has a negative impact on the development of PCO. A larger incision aperture in the posterior capsule may lead to abnormal contraction and healing processes of the capsule opening, creating a microenvironment that is not conducive to normal healing. This change in microenvironment provides more relaxed spatial conditions for the proliferation of lens epithelial cells, making it easier for cells to attach and proliferate near the pocket opening, thereby increasing the risk of PCO recurrence or aggravation. Previous studies [13–14] have also supported this view, pointing out that similar factors related to laser energy and posterior capsule incision aperture play a key role in influencing the development process of PCO. This further confirms the findings of this study.

Based on these factors, this study constructed a column chart prediction model to quantitatively evaluate the risk of PCO in patients receiving Nd: YAG laser treatment after intraocular lens implantation surgery. In the training set and verification set, the C-index index of the nomogram prediction model is 0.870 and 0.842 respectively, the average absolute error of the calibration curve is 0.063 and 0.073 respectively, and the χ^2 value of the Hosmer-Lemeshow test is 4.007($P = 0.856$) and 2.841($P = 0.943$) respectively. The AUC values of ROC curve analysis are 0.870(95% confidence interval: 0.810–0.929) and 0.843(95% confidence interval: 0.732–0.954) respectively. In summary, the column chart prediction model constructed in this study can provide a basis for developing targeted preventive measures in clinical practice. Based on the prediction model constructed in this study, clinicians can assess the risk of PCO in patients before surgery. A series of customized prevention strategies can be implemented for patients with high risk, such as age ≥ 60 years old, patients who intend to undergo extracapsular extraction, select multifocal intraocular lens, patients with axial length ≥ 24 mm, and have poor preoperative vision [15]. For example, more finely treat tissue during surgical procedure, reducing surgical trauma; Postoperative anti-inflammatory treatment should be strengthened to inhibit the inflammatory reaction's irritating effect on lens epithelial cells, and close monitoring of the patient's ocular condition should be strengthened so that possible signs of posterior capsule opacification can be identified early and treated appropriately. Through the implementation of these targeted preventive measures, the long-term efficacy of intraocular lens implantation can be significantly improved, thereby improving the visual status and quality of life of patients [16]. In the process of determining the surgical method and the type of intraocular lens, doctors can comprehensively consider the individual situation of patients and the PCO risk predicted by the model, and weigh the advantages and disadvantages of different treatment options. Patients with higher risks may tend to choose more conservative treatment options with relatively lower risks. For patients with low risk, the surgical method and intraocular lens type can be selected more flexibly on the premise of meeting the visual needs of patients [17].

There are limitations in this study. The sample comes from a single medical institution and is a retrospective study. The sample range is limited, which is prone to selection bias and affects the wide applicability of the research results. Follow-up multi-center and large-sample prospective research should be carried out to better verify the accuracy and reliability of the model [18]. Although there are many influencing factors included in the study, important factors such as genetic factors and systemic metabolic status may be omitted, which may also affect the occurrence of PCO. Subsequent research can further explore the relationship between these potential factors and PCO, and improve the prediction model [19]. In addition, there is no external verification in this study, because of the limited time and resources, it is difficult to complete the collection and processing of large-scale additional data sets in the existing research cycle; It is difficult to obtain suitable external data sets, and the published data sets are different from this study in many aspects, so it is difficult to match; Lack of external cooperation, failure to establish effective cooperation with relevant institutions due to communication and coordination problems, and inability to obtain external data. Future research will solve these problems, carry out external verification, improve the reliability and practicability of the model, and optimize the model to facilitate the application of clinicians [20].

In this study, we analyzed the data of 312 patients with PCO after intraocular lens implantation and receiving Nd: YAG laser treatment, identified the independent risk factors for PCO, and constructed a nomogram prediction model with high accuracy and degree of calibration. The model can provide reference for clinical personalized preventive measures and treatment decisions, reduce the frequency of PCO, and optimize the prognosis of patients. However, there are still some limitations in this study. A multi-center and large-scale study is needed to further improve and optimize the prediction model. Clinicians should combine the patient's situation with comprehensive judgment to improve the treatment effect and patient satisfaction.

Acknowledgements
Not applicable.

Author contributions
Conception and design: Hongmei Chang. Method: Qiang Fang. Data Collection: Hongmei Chang and Xianli Liu. Manuscript Writing: Hongmei Chang. Manuscript revision: Qiang Fang and Xianli Liu. Research supervision: Qiang Fang and Xianli Liu. All authors contributed to the article and approved the submitted version.

Funding
None.

Data availability
The simulation experiment data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of the Zibo Municipal Hospital (No. ZMH-2018022215), and informed consent was obtained from all patients. This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Ophthalmology, Zibo Municipal Hospital, No. 139, Huangong Road, Linzi District, Zibo City, Shandong Province 255400, China
[2]Department of Ophthalmology, 148 Hospital of Zibo City, RongTong Medical Healthcare Group Co. Ltd, Zibo 255300, China

Received: 8 December 2024 / Accepted: 17 March 2025
Published online: 09 April 2025

References

1. Althiabi S, Aljbreen AJ, Alshutily A. Postoperative Endophthalmitis After Cataract Surgery: An Update. Cureus. 2022;8(2):e22003.
2. Moshirfar M, Basharat NF, Seitz TS. Refractive Changes After Nd:YAG Capsulotomy in Pseudophakic Eyes. Clin Ophthalmol. 2023;7:17:135–43.
3. Li X, Li J, Sun D. Development and Validation of a Prediction Model for Nd:YAG Laser Capsulotomy: A Retrospective Cohort Study of 9768 eyes. Ophthalmol Ther. 2023;12(4):1893–912.
4. Dot C, Schweitzer C, Labbé A. Incidence of Retinal Detachment, Macular Edema, and Ocular Hypertension after Neodymium:Yttrium-Aluminum-Garnet Capsulotomy: A Population-Based Nationwide Study-The French YAG 2 Study. Ophthalmology. 2023;130(5):478–87.
5. Icoz M, Tarım B, Icoz SGG. The effect of Nd:YAG Laser applied in the posterior capsule opacification on retinal and choroidal structures. Photodiagnosis Photodyn Ther. 2023;43:103653.
6. Brézin AP, Labbe A, Schweitzer C. Incidence of Nd:YAG laser capsulotomy following cataract surgery: a population-based nation-wide study - FreYAG1 study. BMC Ophthalmol. 2023;16(1):417.
7. Yong GY, Mohamed-Noor J, Salowi MA. Risk factors affecting cataract surgery outcome: The Malaysian cataract surgery registry. PLoS ONE. 2022;21(9):e0274939.
8. Li A, He Q, Wei L. Comparison of visual acuity between phacoemulsification and extracapsular cataract extraction: a systematic review and meta-analysis. Ann Palliat Med. 2022;11(2):551–9.
9. Bai G, Li X, Zhang S. Analysis of visual quality after multifocal intraocular lens implantation in post-LASIK cataract patients. Heliyon. 2023;22(5):e15720.
10. Shen W, Zhuo B, Zhang L. Effect of astigmatism on visual outcomes after multifocal intraocular lens implantation: a systematic review and meta-analysis. Front Med (Lausanne). 2023;28:10:1214714.
11. Ramin S, Nabovati P, Hashemi H. To compare on-axis measurements of the axial length with off-axis measurements in the paracentral horizontal and vertical positions. Semin Ophthalmol. 2022;2(1):63–6.
12. Fernández J, Alfonso Sánchez JF, Nieradzik M. Visual performance, safety and patient satisfaction after bilateral implantation of a trifocal intraocular lens in presbyopic patients without cataract. BMC Ophthalmol. 2022;10(1):341.
13. Tariq M, Iqbal K, Inayat B. Impact of Neodymium-Doped Yttrium Aluminum Garnet (ND-YAG) Posterior Capsulotomy Laser Treatment on Central Macular Thickness: A Prospective, Observational Study From a Tertiary Care Center. Cureus. 2021;7(7):e16242.
14. Konopińska J, Młynarczyk M, Dmuchowska DA. Posterior Capsule Opacification: A Review of Experimental Studies. J Clin Med. 2021;27(13):2847.

15. Apple DJ, Peng Q, Visessook N. Eradication of Posterior Capsule Opacification: Documentation of a Marked Decrease in Nd:YAG Laser Posterior Capsulotomy Rates Noted in an Analy sis of 5416 Pseudophakic Human Eyes Obtained Postmortem. Ophthalmology. 2020;127(4S):S29–42.
16. Maedel S, Evans JR, Harrer-Seely A. Intraocular lens optic edge design for the prevention of posterior capsule opacification after cataract surgery. Cochrane Database Syst Rev. 2021;16(8):CD012516.
17. Darian-Smith E, Safran SG, Coroneo MT. Lens Epithelial Cell Removal in Routine Phacoemulsification: Is It Worth the Bother? Am J Ophthalmol. 2022;239:1–10.
18. Bontu S, Werner L, Kennedy S. Long-term uveal and capsular biocompatibility of a new fluid-filled, modular accommodating intraocular lens. J Cataract Refract Surg. 2021;1(1):111–7.
19. Wang JD, Zhang JS, Li XX. Knockout of TGF-β receptor II by CRISPR/Cas9 delays mesenchymal transition of Lens epithelium and posterior capsule opacification. Int J Biol Macromol. 2024;259(Pt 2):129290.
20. Gutierrez L, Lim JS, Foo LL. Application of artificial intelligence in cataract management: current and future directions. Eye Vis (Lond). 2022;7(1):3.

Publisher's note