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Original Article

Analysis of factors influencing the efficacy of YAG laser vitreolysis for symptomatic vitreous opacities and prediction of postoperative complication risks: a retrospective cohort study

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Abstract: Objective: To identify factors influencing the efficacy of Yttrium Aluminum Garnet (YAG) laser vitreolysis for symptomatic vitreous opacities and to establish a risk prediction model for postoperative complications. Methods: This retrospective study included 130 patients with symptomatic vitreous opacities who underwent YAG laser vitreolysis from January 2022 to December 2024. The relationships between patient demographics, clinical characteristics, surgical parameters, and treatment efficacy were analyzed. Multivariate logistic regression was applied to identify independent predictive factors for treatment efficacy. A risk prediction model for complications was constructed and evaluated using receiver operating characteristic (ROC) curve analysis. Results: At 3 months postoperatively, 78 (60.0%), 32 (24.6%), and 20 (15.4%) patients experienced marked, partial, and no improvement, respectively. Multivariate analysis identified age (OR=1.052, 95% CI: 1.012-1.093), disease duration (OR=1.105, 95% CI: 1.032-1.183), degree of vitreous opacity (OR=2.356, 95% CI: 1.325-4.187), and laser energy (OR=1.872, 95% CI: 1.235-2.841) as independent factors influencing efficacy (all P<0.05). Postoperative complications occurred in 70 (53.8%) patients. The prediction model demonstrated good performance, with an area under the curve (AUC) of 0.792, sensitivity of 0.714, and specificity of 0.667. Conclusions: The efficacy of YAG laser vitreolysis is influenced by multiple factors. The established complication risk prediction model shows good predictive ability and may aid clinical decision-making.

Keywords: Yttrium Aluminum Garnet (YAG) laser vitreolysis, symptomatic vitreous opacities, efficacy, influencing factors, postoperative complications, risk prediction

Introduction

Symptomatic vitreous opacities, a common clinical ophthalmic condition, are pathologically characterized by vitreous liquefaction and degeneration [1, 2]. The vitreous, a transparent gel-like substance within the eye, undergoes structural changes with aging or other influencing factors, leading to the collapse of the collagen fiber scaffold and fluid separation, resulting in vitreous liquefaction. During this process, the originally uniform vitreous structure is disrupted, forming opacities [3]. These opacities move with eye motion, resulting in sensing of floaters and moving dark spots in the visual field [4-6]. These symptoms severely compromise visual function during daily activities, such as reading and driving [7, 8]. Simultaneously, long-term visual distress negatively impacts patients' psychological well-being, inducing anxiety, irritability, and other emotions, significantly reducing their quality of life [9, 10]. Therefore, finding effective treatments to alleviate symptoms has become an urgent issue in ophthalmology [11].

With advancements in medical technology, YAG laser vitreolysis has emerged as an important treatment for symptomatic vitreous opacities [12]. This technique utilizes the photodisruptive effect of a laser to fragment and vaporize vitreous opacities [11, 13]. By precisely controlling

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laser parameters such as energy, pulses, and spot size, the laser can directly target opacities, breaking them down into microscopic particles that can be subsequently absorbed by the body or eliminated through the aqueous humor circulation, thereby improving symptoms [14]. Compared to traditional surgical approaches, YAG laser vitreolysis offers advantages such as minimal invasiveness and rapid recovery [6, 15].

However, in clinical practice, the therapeutic efficacy of YAG laser vitreolysis varies significantly between individuals. Some patients experience marked symptom improvement and enhanced visual function and quality of life postoperatively; yet a considerable proportion of patients show little symptom improvement, with treatment outcomes falling short of expectations. Another concern is that the procedure may trigger a series of complications, such as vitreous hemorrhage and retinal damage [16]. Vitreous hemorrhage can result in sudden vision loss, and if the bleeding does not resolve promptly, it may lead to other ocular complications [17]. Retinal damage, in particular, could severely impair visual function, potentially leading to blindness and other serious outcomes [18]. These conditions not only affect treatment efficacy and safety but also present significant challenges for clinical management [19].

In-depth research into factors influencing the efficacy of YAG laser vitreolysis and prediction of postoperative complication risks hold significant clinical importance. Clarifying factors affecting efficacy helps physicians conduct comprehensive preoperative assessments, develop personalized treatment plans based on individual patient conditions, optimize surgical parameters, and thereby improve treatment success rates. Effective prediction of postoperative complication risks enables physicians to identify high-risk patients early and implement targeted preventive measures, reducing complication incidence and ensuring ocular safety [20].

Currently, research on YAG laser vitreolysis for symptomatic vitreous opacities primarily focuses on observing surgical outcomes, such as the proportion of symptom improvement and visual acuity changes postoperatively. However, systematic and in-depth analyses of factors influencing efficacy - such as patient age, disease duration, characteristics of opacities, and surgical parameters - are lacking. Research on postoperative complication risk prediction is even more limited, with no effective predictive models established yet [21].

This study conducted a retrospective analysis of multicenter clinical data to systematically investigate key factors influencing the efficacy of YAG laser vitreolysis for symptomatic vitreous opacities. Simultaneously, based on collected clinical data, a predictive model was constructed for postoperative complication risk prediction. The goal of this study is to provide solid theoretical evidence for clinical practice, assist physicians in better treatment selection, and enhance the effectiveness and safety of the procedure, ultimately improving patient outcomes and quality of life.

Materials and methods

Patient selection

A total of 130 patients with symptomatic vitreous opacity who underwent YAG laser vitreolysis at the Ophthalmology Center of the Third Affiliated Hospital of Shandong University (Shandong Provincial Third Hospital) from January 2022 to December 2024 were retrospectively selected for this study. The study was approved by the Ethics Committee of the Shandong Provincial Third Hospital, Shandong University, and patients' informed consent was waived due to the retrospective nature of the study and the use of anonymized data. All procedures performed in this study involving human participants adhered to the Declaration of Helsinki (as revised in 2013).

Inclusion criteria

Diagnosed with symptomatic vitreous opacity, confirmed by clinical examinations (e.g., fundus examination, optical coherence tomography, etc.); underwent YAG laser vitreolysis; Complete clinical data and follow-up (at least 3 months) data available; Ability to cooperate with treatment.

Exclusion criteria

Presence of other ocular diseases such as retinal detachment, glaucoma, and severe cataract; History of ocular surgery (except for the

surgery in this study); Uncontrolled systemic diseases, including diabetes mellitus (fasting blood glucose ≥7.0 mmol/L or 2-hour postprandial blood glucose ≥11.1 mmol/L) or hypertension (systolic blood pressure ≥140 mmHg or diastolic blood pressure ≥90 mmHg); Incomplete clinical data, preventing evaluation of efficacy and complications; Loss to follow-up or refusal to continue participation during the study period.

Surgical methods

All surgeries were performed by experienced ophthalmologists using the VISULAS YAG III YAG laser therapy device. Patients were seated, and after topical anesthesia, a contact lens was placed to target vitreous opacities for laser irradiation. The laser energy was set at 0.8-2.4 mJ, and the number of irradiations was adjusted according to the size and density of the opacities. Each surgery involved 50-150 irradiations, with a total duration of 5-15 minutes.

Data collection

In this study, clinically relevant data of patients were systematically collected by reviewing the electronic medical record systems of each research center, covering general information, clinical data, surgical data, and postoperative follow-up data. General information included age, sex, height, weight, and past medical history (such as diabetes, hypertension). Clinical data included disease duration (defined as the time from symptom onset to surgery), degree of vitreous opacity (classified as mild, moderate, or severe based on fundus examination results), preoperative visual acuity (measured using the international standard visual acuity chart), and fundus examination findings. Surgical data included laser energy, number of irradiations, and surgical duration. Postoperative follow-up data included changes in visual acuity, degree of symptom improvement (assessed using the Floaters Symptom Rating Scale), and occurrence of complications at 1 day, 1 week, 1 month, and 3 months after surgery. To ensure the accuracy and completeness of the data, designated personnel were assigned to be responsible for data collection. A uniformly designed data collection form was used, and a double independent verification mechanism was implemented to cross-verify all entered data, thereby ensuring data quality.

Outcome measurements

Primary outcomes: Symptom improvement was evaluated at 3 months postoperatively using the Floaters Symptom Rating Scale. This scale assesses the number, size, and frequency of floaters appearing in the visual field, with a total score ranging from 0 to 10. A higher score indicates more severe symptoms. Treatment efficacy was categorized based on the percentage reduction in the symptom score: marked improvement was defined as a score reduction of 70% or greater, partial improvement as a reduction between 30% and 69%, and no improvement as a reduction of less than 30%.

Secondary outcomes: Changes in patients' visual acuity were evaluated at 3 months postoperatively. The number of improved visual acuity lines was calculated by comparing postoperative visual acuity with preoperative baseline measurements.

Definition and observation of postoperative complications

Vitreous hemorrhage was defined as the accumulation of red blood cells in the vitreous cavity, detected through fundus examination following surgery. Retinal injury encompassed conditions such as retinal burns and retinal holes, which were confirmed via clinical examinations including fundus evaluation and optical coherence tomography (OCT). Other complications included elevated intraocular pressure (defined as intraocular pressure >21 mmHg) and signs of inflammatory response, such as conjunctival hyperemia and edema. The postoperative observation time points were set at 1 day, 1 week, 1 month, and 3 months postoperatively.

Statistical analysis

All statistical analyses were performed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Normally distributed continuous data were presented as mean ± standard deviation, and categorical data were expressed as frequencies and percentages. For the analysis of factors influencing treatment efficacy, pa-

tients were divided into three groups (marked improvement, partial improvement, and no improvement). Inter-group comparisons were conducted using one-way ANOVA for continuous variables, followed by post-hoc Tukey's test for pairwise comparisons. The Chi-square test or Fisher's exact test was applied for categorical variables, as appropriate. Variables that demonstrated a significance level of P<0.1 in the univariate analysis and/or were deemed clinically relevant were entered into a multivariate logistic regression model (forward: LR method) to identify independent factors influencing treatment efficacy. The results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). For the complication risk prediction model, a similar approach was adopted. Significant predictors from univariate analysis were included in a multivariate logistic regression to construct the model. The model's discriminative ability was evaluated by the ROC curve and the AUC, with sensitivity and specificity reported. The model's calibration was assessed using the Hosmer-Lemeshow goodness-of-fit test. Furthermore, the clinical utility of the prediction model was quantified using decision curve analysis (DCA). A two-tailed *P*-value of <0.05 was considered statistically significant.

Results

Baseline characteristics

According to postoperative efficacy, the included patients were categorized into a significantly improved group (n=78), a partially improved group (n=32), and a non-improved group (n=20). Baseline data analysis showed significant differences among the three groups in age, degree of vitreous opacity, presence of posterior vitreous detachment (PVD), disease duration, laser energy, number of laser pulses, procedure duration, lens opacity grade, axial length, preoperative intraocular pressure (IOP), degree of myopia, vitreoretinal interface abnormalities observed on preoperative OCT, location of vitreous opacities, presence of preoperative photopsia, corneal thickness, retinal vessel diameter, floater mobility score, history of uveitis, and laser spot size (P<0.05). Specifically, patients in the non-improved group were older, had longer disease duration, more severe vitreous opacities, higher laser energy and number of pulses, and longer procedure duration. They also had greater axial length, higher preoperative IOP, higher myopia degree, thicker corneas, and larger retinal vessel diameter. Additionally, the non-improved exhibited a lower incidence of PVD, a higher proportion of peripheral opacities, a higher proportion of patients with preoperative photopsia, a relatively higher prevalence of lens opacity and vitreoretinal interface abnormalities, lower floater mobility scores, a higher proportion with a history of uveitis, and larger laser spot sizes.

In contrast, no significant differences were observed among the three groups regarding sex, history of diabetes, history of hypertension, presence of other ocular diseases (e.g., glaucoma, cataract), history of ocular surgery (other than in this study), preoperative visual acuity, preoperative floater symptom score, family history of vitreous opacities, prior pharmacological treatment, or presence of retinal degeneration on preoperative fundus examination (P>0.05, **Table 1**).

At the 3-month postoperative follow-up, visual acuity increased in 85 patients (65.4%), remained unchanged in 30 (23.1%), and decreased in 15 (11.5%). The mean improvement in visual acuity was (1.2±0.5) lines.

Analysis of factors influencing laser efficacy

Univariate analysis: Univariate analysis showed that age, disease duration, severity of vitreous opacities, laser energy, and number of laser applications were significantly associated with therapeutic efficacy (P<0.05). In contrast, sex, body weight, preoperative visual acuity, and operative duration showed no significant correlation with treatment outcomes (P>0.05; **Table 1**).

Multivariate logistic regression analysis: Factors that showed statistical significance in the univariate analysis were included in the multivariate Logistic regression analysis. The results identified age (OR=1.052, 95% CI: 1.012-1.093), disease duration (OR=1.105, 95% CI: 1.032-1.183), degree of vitreous opacity (OR=2.356, 95% CI: 1.325-4.187), and laser energy (OR=1.872, 95% CI: 1.235-2.841) as independent factors influencing treatment efficacy (P<0.05, **Figure 1**).

Table 1. Baseline characteristics of enrolled patients

Variable	Total (n=130)	Significant improvement group (n=78)	Partial improvement group (n=32)	No improvement group (n=20)	χ^2/F	*P* value
Age (years, Mean ± SD)	52.31±10.52	50.23±8.63	53.52±9.21	58.73±10.14	7.438	0.015
Sex (Male/Female, n)	72/58	45/33	18/14	9/11	0.964	0.546
History of diabetes mellitus					1.894	0.387
Yes (case, %)	15 (11.5%)	7 (9.0%)	4 (12.5%)	4 (20.0%)		
No (case, %)	115 (88.5%)	71 (91.0%)	28 (87.5%)	16 (80.0%)		
History of hypertension					1.869	0.303
Yes (case, %)	22 (16.9%)	10 (12.8%)	7 (21.9%)	5 (25.0%)		
No (case, %)	108 (83.1%)	68 (87.2%)	25 (78.1%)	15 (75.0%)		
Complicated with other ocular diseases (glaucoma/cataract, etc.)					2.294	0.405
Yes (case, %)	10 (7.7%)	4 (5.1%)	3 (9.4%)	3 (15.0%)		
No (case, %)	120 (92.3%)	74 (94.9%)	29 (90.6%)	17 (85.0%)		
History of ocular surgery (except this study)					1.800	0.406
Yes (case, %)	8 (6.2%)	3 (3.8%)	3 (9.4%)	2 (10.0%)		
No (case, %)	122 (93.8%)	75 (96.2%)	29 (90.6%)	18 (90.0%)		
Degree of vitreous opacity					19.157	0.006
Mild (n, %)	35 (26.9%)	25 (71.4%)	8 (22.9%)	2 (5.7%)		
Moderate (n, %)	60 (46.2%)	40 (66.7%)	15 (25.0%)	5 (8.3%)		
Severe (n, %)	35 (26.9%)	13 (37.1%)	9 (25.7%)	13 (37.2%)		
Status of posterior vitreous detachment (PVD)					10.874	0.032
Yes (case, %)	85 (65.4%)	58 (74.4%)	20 (62.5%)	7 (35.0%)		
No (case, %)	45 (34.6%)	20 (25.6%)	12 (37.5%)	13 (65.0%)		
Preoperative visual acuity (Mean ± SD)	0.51±0.22	0.52±0.18	0.48±0.21	0.45±0.19	1.512	0.273
Course of disease (months, Mean ± SD)	10.21±5.82	8.53±4.21	11.32±5.13	15.61±6.32	18.206	0.003
Laser energy (mJ, Mean ± SD)	6.12±1.43	5.21±1.12	6.53±1.31	7.82±1.53	41.778	0.002
Irradiation frequency (times, Mean ± SD)	17.31±4.22	15.23±3.51	18.62±4.23	22.51±5.12	29.593	0.007
Operation time (minutes, Mean ± SD)	12.52±3.11	11.83±2.82	13.21±3.33	14.52±3.51	7.060	0.021
Degree of lens opacity					1.208	0.043
None (case, %)	62 (47.7%)	38 (48.7%))	16 (50.0%)	8 (40.0%)		
Mild (case, %)	45 (34.6%)	25 (32.1%)	12 (37.5%)	8 (40.0%)		
Moderate (case, %)	23 (17.7%)	15 (19.2%)	4 (12.5%)	4 (20.0%)		
Ocular axial length (mm, Mean ± SD)	23.8±1.5	23.5±1.3	24.0±1.6	24.5±1.8	4.241	0.028
Preoperative intraocular pressure (mmHg, Mean ± SD)	16.21±2.32	15.83±2.11	16.52±2.43	17.13±2.51	3.076	0.035
Myopia degree (diopter, Mean ± SD)	-3.21±2.52	-2.83±2.31	-3.52±2.63	-4.11±2.82	2.498	0.019

Family history of vitreous opacity					1.247	0.587
Yes (case, %)	18 (13.8%)	9 (11.5%)	5 (15.6%)	4 (20.0%)		
No (case, %)	112 (86.2%)	69 (88.5%)	27 (84.4%)	16 (80.0%)		
Preoperative optical coherence tomography (OCT) showing vitreoretinal interface abnormalities					2.987	0.047
Yes (case, %)	42 (32.3%)	22 (28.2%)	12 (37.5%)	8 (40.0%)		
No (case, %)	88 (67.7%)	56 (71.8%)	20 (62.5%)	12 (60.0%)		
Preoperative medication history					1.632	0.423
Yes (case, %)	25 (19.2%)	12 (15.4%)	8 (25.0%)	5 (25.0%)		
No (case, %)	105 (80.8%)	66 (84.6%)	24 (75.0%)	15 (75.0%)		
Location of vitreous opacities					5.515	0.031
Central area (case, %)	58 (44.6%)	38 (48.7%)	12 (37.5%)	8 (40.0%)		
Peripheral area (case, %)	42 (32.3%)	22 (28.2%)	10 (31.3%)	10 (50.0%)		
Mixed area (case, %)	30 (23.1%)	18 (23.1%)	10 (31.3%)	2 (10.0%)		
Preoperative photopsia					8.065	0.009
Yes (case, %)	35 (26.9%)	15 (19.2%)	10 (31.3%)	10 (50.0%)		
No (case, %)	95 (73.1%)	63 (80.8%)	22 (68.7%)	10 (50.0%)		
Corneal thickness (μm, Mean ± SD)	542.1±35.2	538.3±32.1	545.2±36.3	552.1±38.2	1.474	0.042
Retinal vessel diameter (μm, Mean ± SD)	145.20±18.10	142.30±16.20	148.10±19.30	153.20±20.10	3.551	0.026
Mobility score of black shadow (1-3 points, Mean ± SD)	2.12±0.61	2.33±0.52	2.01±0.73	1.72±0.61	10.047	0.012
Preoperative best-corrected visual acuity (Mean ± SD)	0.61±0.22	0.63±0.19	0.58±0.22	0.55±0.21	1.638	0.191
History of uveitis					5.872	0.048
Yes (case, %)	9 (6.9%)	3 (3.8%)	3 (10.3%)	3 (17.6%)		
No (case, %)	121 (93.1%)	75 (96.2%)	29 (89.7%)	17 (82.4%)		
Laser spot size (μm, Mean ± SD)	50.10±10.20	48.30±8.10	52.20±11.30	55.10±12.20	4.794	0.037

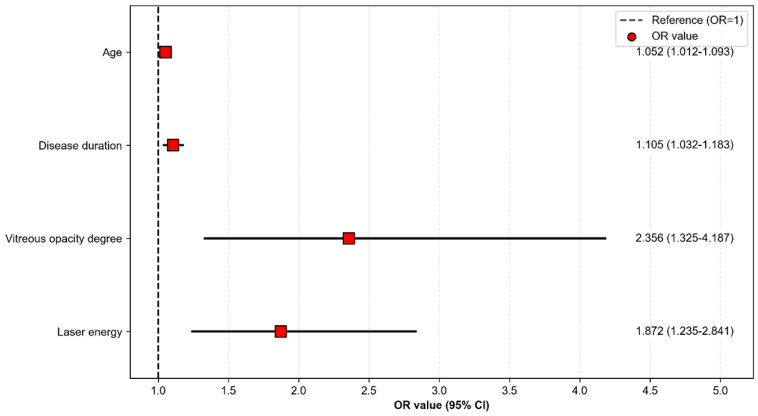

Figure 1. Forest plot of multivariate logistic regression analysis for treatment efficacy predictors.

Table 2. Postoperative complications

Complication Type	Number of Cases (n)	Percentage (%)
No Complications	60	46.2
Vitreous Hemorrhage	20	15.4
Retinal Injury	25	19.2
Elevated Intraocular Pressure	10	7.7
Inflammation	5	3.8
Total with Complications	70	53.8

Overall incidence of postoperative complications

Analysis of postoperative complications showed that 46.2% of patients experienced no complications, while 53.8% experienced complications (**Table 2**).

Temporal distribution characteristics of postoperative complications

Analysis of the temporal distribution of postoperative complications showed that the number of cases without complications was the highest (nearly 60 cases), consistent with the previously mentioned characteristic of "low incidence of complications". Cases with complications were concentrated at post-operative 1 day and 1 week (both nearly 30 cases), showing a decreasing trend at 1 month (about 12 cases) and 3 months (fewer than 5 cases) after surgery. These findings indicate that the early postoperative period (1 day to 1 week) is the peak incidence window for complications, which may be associated with immediate surgical effects (such as inflammation, fluctuations in intraocular pressure) (**Figure 2**).

Distribution characteristics of types of postoperative complications

Analysis of complication types showed that patients without complications were absolutely dominant (nearly 60 cases). Among specific complication types, inflammation showed the lowest incidence (about 5 cases), followed by elevated intraocular pressure, vitreous hemorrhage, and retinal damage increased in turn (with 10, 20, and 25 cases, respectively).

As shown in **Figure 3**, the distribution pattern highlights the heterogeneity and low-incidence postoperative complications, while emphasizing retinal damage and vitreous hemorrhage as relatively more common events, providing a basis for subsequent analyses of risk factors for key complications (e.g., laser energy and surgical duration) and for further optimization of prediction models.

Correlation analysis between characteristic variables

Using a heatmap of feature correlations based on Pearson correlation coefficients, we systematically evaluated the linear association patterns between the 12 clinical and surgical features (including age, preoperative visual acuity [Preop_VA], and surgical parameters such as laser energy and surgical duration) and postoperative complications. The results showed a strong positive correlation between laser energy and energy per spot (r=0.758), and a strong negative correlation between surgical duration and surgical intensity (r=-0.656), suggesting high collinearity within these two groups of features. It is necessary to avoid the interference of multicollinearity on parameter estimation through regularization or dimensionality reduction strategies during model construction; Moderate positive correlations were observed between risk factors and surgical intensity (r=0.602), as well as between risk factors and laser energy (r=0.426), reflecting that high-

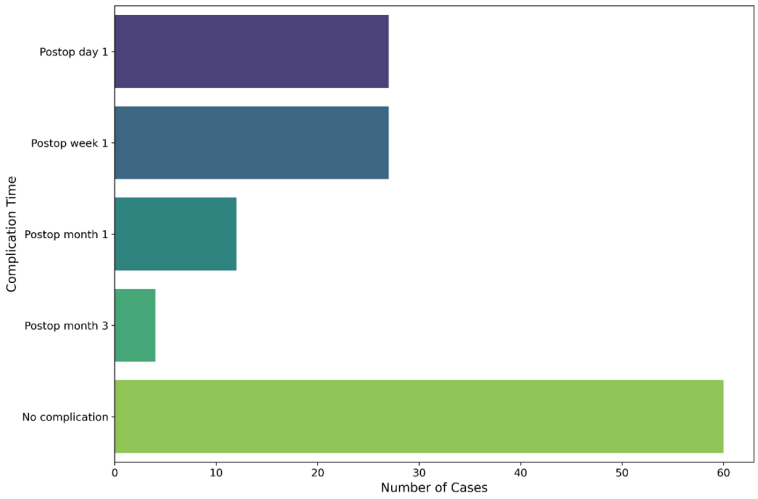

Figure 2. Temporal distribution characteristics of postoperative complications.

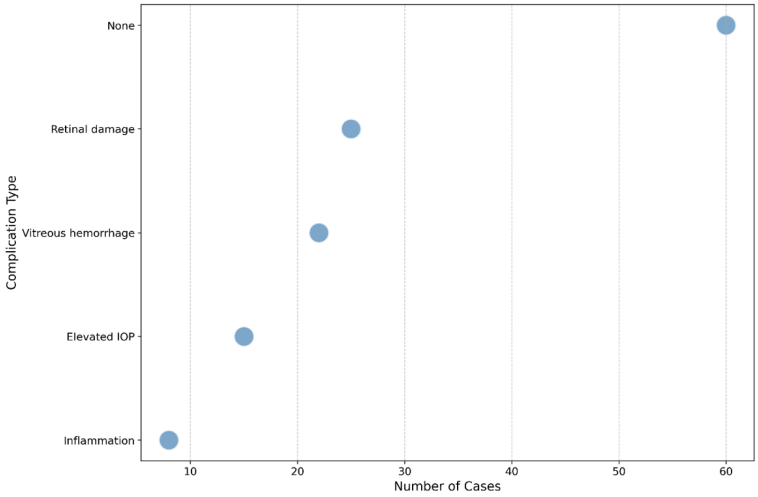

Figure 3. Distribution of the number of cases by type of postoperative complications.

risk patients may receive more intensive surgical intervention strategies, which provides clues for subsequent analysis of feature interaction effects; Potential associations were found between postoperative complications and surgical duration (r=-0.348), as well as between postoperative complications and laser energy (r=0.188, **Figure 4**).

Development of the complication risk prediction model

To construct a risk prediction model for post operative complications, significant variables identified as potentially relevant from the univariate analysis and the correlation heatmap (**Figure 4**) were considered. These included laser energy, surgical duration, and other clinically significant baseline characteristics. Using the forward likelihood ratio method as detailed in the statistical analysis section, multivariate logistic regression analysis was performed to identify independent predictors. The results demonstrated that laser energy, surgical duration, and the degree of vitreous opacity were independent factors significantly associated with the risk of postoperative complications (**Table 3**).

The final prediction model was formulated as follows: Logit (P) = - 4.85 + 0.521 × Laser energy (mJ) - 0.184 × Surgical duration (minutes) + 0.793 × Degree of vitreous opacity (1= mild, 2= moderate, 3= severe), where P represents the probability of postoperative complication occurrence. The model was internally validated using bootstrap resampling (1000 iterations), which showed good consistency.

Validation of the complication risk prediction model

The model's predictive performance was evaluated using multiple approaches. The ROC curve analysis yielded an AUC of 0.792 (95% CI: 0.701-0.883), with a sensitivity of 0.714 and specificity of 0.667 at the optimal cutoff point (**Figure 5A**). The Precision-Recall curve further confirmed the model's robustness, with an AUC of 0.82 (**Figure 5B**). Decision curve analysis demonstrated that the model provided a positive net benefit across a wide range of threshold probabilities, supporting its clinical utility (**Figure 5C**). These results collectively indicate that the model has good discriminative ability and practical value for predicting postoperative complications (**Figure 5**).

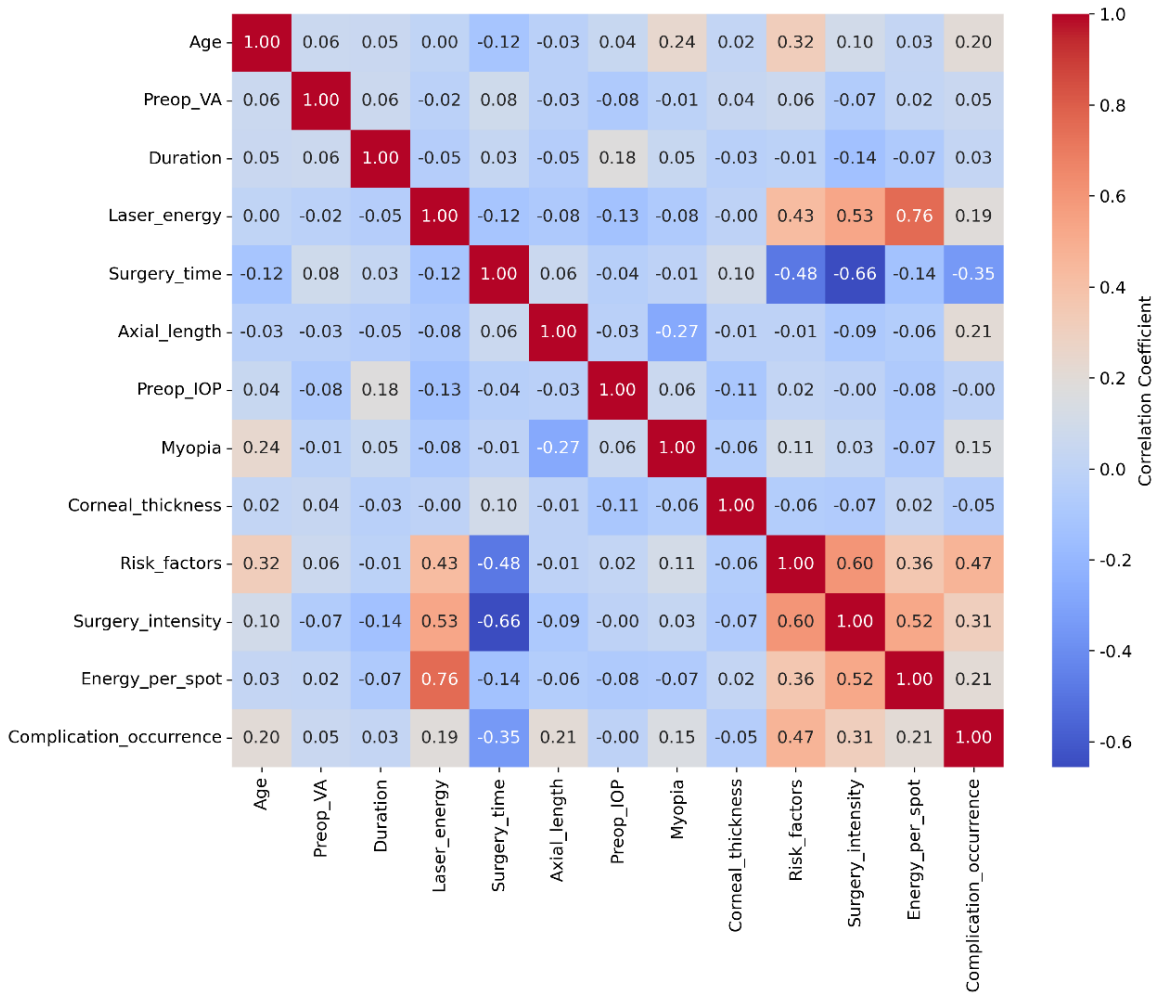

Figure 4. Heatmap of feature correlations.

Table 3. Multivariate logistic regression analysis of independent predictors for postoperative complications

Variable	β coefficient	OR (95% CI)	*P* value
Laser energy (mJ)	0.521	1.684 (1.205-2.352)	0.002
Surgical duration (minutes)	-0.184	0.832 (0.712-0.972)	0.021
Degree of vitreous opacity	0.793	2.210 (1.251-3.905)	0.006

Discussion

Symptomatic vitreous opacities are a prevalent condition in clinical ophthalmology, pathologically characterized by vitreous liquefaction and degeneration of the collagen fiber scaffold [18]. Driven by an aging population and increasing prevalence of refractive errors, the incidence of vitreous opacities is rising annually [22, 23]. The resultant floaters and visual field obstructions significantly impair functional capabilities such as reading and driving, with approximately 65% of patients with moderate to severe symptoms reporting functional impairments and 30% experiencing psychological distress, leading to a marked reduction in quality of life [24]. While traditional vitrectomy is effective but invasive, and pharmacological options lack robust evidence [7, 16, 25], YAG laser vitreolysis has emerged as a promising minimally invasive alternative [21]. However, its clinical application is hampered by significant variability in efficacy and non-negligible complication risks, underscoring the need to identify reliable predictors and improve safety stratification [3, 9, 14].

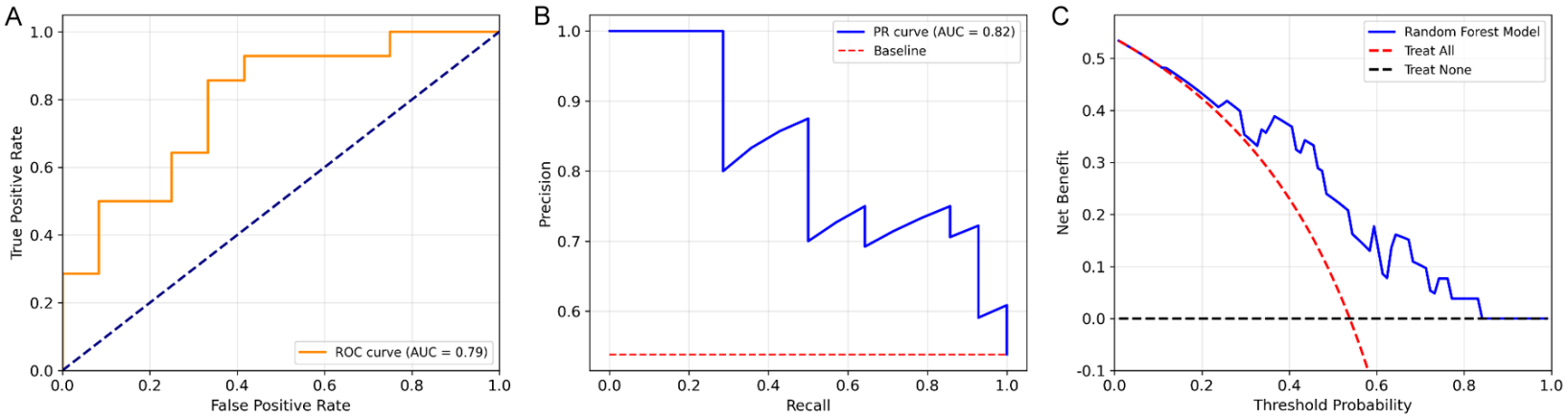

Figure 5. Comprehensive model evaluation: predictive performance and clinical utility analysis. A. Receiver Operating Characteristic Curve; B. Precision-Recall Curve; C. Decision Curve Analysis.

Our study provides a systematic analysis that identifies age, disease duration, vitreous opacity density, and laser energy as independent determinants of YAG laser vitreolysis outcome. The negative correlation between age and treatment success can be attributed to age-related structural changes in the vitreous. In older patients, opacities often evolve from loose particles to dense, fibrous strands with reduced mobility (as evidenced by the lower floater mobility score of 1.7±0.6 in our non-improved group), complicating laser targeting and fragmentation. Similarly, longer symptom duration was a strong negative predictor. The mean disease duration in the non-improved group was 15.6±6.3 months, notably longer than the 8.5±4.2 months in the significantly improved group. Chronic opacities may become organized and firmly integrated into the vitreous matrix, rendering them more resistant to laser vaporization. Our results, which are consistent with the findings of Sim et al. [19], suggest that early intervention may yield superior outcomes.

Furthermore, laser energy demonstrated a "double-edged sword" effect. While adequate energy is necessary for effective photodisruption, the higher mean energy observed in the non-improved group (7.8±1.5 mJ) compared with the significantly improved group (5.2±1.1 mJ) implies that excessive energy does not confer additional benefit and may instead promote vitreous matrix damage and inflammation. This underscores the importance of individualized energy titration over standardized high-dose protocols.

The postoperative complication rate of 11.5% in our cohort, dominated by vitreous hemorrhage and retinal injury, is consistent with the range reported in the literature (5%-15%) [14, 26]. A key contribution of this study is the development of a risk prediction model that integrates patient-specific factors (e.g., age, opacity density) with surgical parameters (e.g., laser energy). The model's good discriminative ability (AUC=0.792) represents a significant advancement beyond subjective clinical judgment. It provides a quantitative tool for preoperative risk stratification, potentially enabling tailored surgical planning, enhanced patient counseling, and proactive safety measures for high-risk individuals.

The limitations of this study must be acknowledged. Its single-center, retrospective design may introduce selection bias and limits the generalizability of our findings. The sample size, while substantial, may still be underpowered to detect all potentially significant predictors, such as specific opacity types. The absence of detailed, standardized opacity classification and external validation for our predictive model, represents critical limitations of this study. Future prospective, multicenter studies with larger cohorts, longer follow-up, and advanced imaging biomarkers are essential to validate and refine our model, thereby strengthening its clinical translatability and utility.

Conclusion

The efficacy of YAG laser vitreolysis for symptomatic vitreous opacities is influenced by multiple factors, including age, disease duration, degree of vitreous opacity, and laser energy. The postoperative complication risk prediction model established in this study demonstrates good predictive performance, providing a reference for clinical decision-making, helping to improve treatment outcomes and reduce complication rates.

Disclosure of conflict of interest

None.

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