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Ocular hypertension after silicone oil filling surgery for high myopia: a case-control study

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Abstract

Purpose This study aims to examine the correlation between specific clinical parameters, such as axial eye length, and the onset of ocular hypertension "OH" following the use of silicone oil filling in patients with high myopia.

Method In this retrospective analysis, we reviewed 214 eyes from 432 patients diagnosed with severe myopia, all of whom underwent vitrectomy and were treated with silicone oil filling. The study aimed to document the incidence and timing of postoperative ocular hypertension "OH" while assessing various factors, including demographic details, medical history, additional surgical interventions, and findings from supplementary examinations (such as axial length, silicone oil emulsification, and anterior chamber penetration). Binary logistic regression was employed as the primary statistical method to identify significant predictors and their relationship with "OH". This approach allowed for a comprehensive analysis of the impact of the duration of silicone oil presence in the eye on "OH" occurrence, providing a detailed understanding of the factors influencing post-surgical outcomes.

Result The study revealed a statistically significant increase in postoperative axial length (29.21 ± 0.85 mm) compared to the preoperative length (28.31 ± 0.82 mm), corresponding to an incidence rate of 37.38% (80 cases) for "OH". Logistic regression analysis identified the following variables as significantly associated with an increased risk of "OH" post-silicone oil filling: scleral buckling, aphakic status, silicone oil emulsification, and silicone oil penetration into the anterior chamber. The odds ratios (OR) for these variables were 1.397, 0.672, 1.859, and 1.364, respectively, indicating their predictive value for "OH" risk.

Conclusion The development of "OH" post-silicone oil filling is strongly correlated with changes in the anterior segment anatomy and the dynamics of aqueous humor flow, particularly in eyes without the natural lens. Recognizing these risk factors highlights the importance of thorough preoperative evaluation and individualized postoperative care to reduce the incidence of OH in patients with high myopia, thereby improving surgical outcomes.

Keywords Silicone oil, Silicone oil filling, High myopia, Axial length, Ocular hypertension

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Introduction

The molecular formula of silicone oil is $C_6H_{18}OSi_2$, a polyorganosiloxane with a chain structure of varying polymerization degrees. Silicone oil is known for its stable physical and chemical properties and its excellent biocompatibility [1–4]. It exhibits several beneficial characteristics, including heat resistance, electrical insulation, weather resistance, hydrophobicity, physiological inertness, and low surface tension. Additionally, it has a low viscosity-temperature coefficient and high compressive strength. Silicone oil is also non-toxic and safe for human use [5]. Its diverse properties make it valuable in various applications, not only as a specialized material in aviation, cutting-edge technology, and military applications but also across multiple sectors of the economy. It is widely used in construction, electronics, textiles, automobiles, machinery, leather, paper, chemicals, metalwork, paints, medicine, and healthcare [6].

Meanwhile Cibis [7] first used silicone oil as a vitreous substitute in retinal detachment surgery in 1962, it has become a vital tool in treating retinal detachment, providing effective results for numerous patients. With advancements in vitreous microsurgery, silicone oil has emerged as one of the most effective intraocular fillers following vitrectomy. Its stable physical and chemical properties and good biocompatibility significantly increase the success rate of complex retinal detachment repairs. Today, silicone oil is an integral component of modern vitreous surgery [8]. During vitrectomy, silicone oil fills the vitreous cavity and forms a stable silicone oil bubble that presses against the retina. This changes the pulling force on the retina from a radial direction to a parallel force, which restricts fibroblast migration and other biological media within the vitreous cavity, thereby inhibiting retinal proliferative pathology. It also reduces the entry of neovascular factors from the ischemic retina into the anterior segment of the eye, helping stabilize or reduce iris neovascularization. However, the complications arising from this procedure have significantly affected the recovery of patients' visual function [9]. Common complications include cataracts, secondary high intraocular pressure (IOP) or even glaucoma, corneal degeneration, retinal hemorrhage, and retinal toxicity [10, 11]. The inherent complexity of the conditions treated in these surgeries further contributes to the occurrence and complexity of these complications.

Ocular hypertension "OH" is a potential risk factor for optic nerve damage, which may lead to permanent visual impairment [12]. In recent years, various studies have investigated the risk factors associated with secondary "OH" following silicone oil filling. However, these studies have reported differing results [13, 14]. The exact pathogenesis of "OH" post-silicone oil filling remains unclear and is likely multifactorial. This study aims to further elucidate the pathogenesis of "OH" following silicone oil filling, with the goal of reducing this serious complication and improving postoperative outcomes in vitreoretinal surgery.

Materials and methods

Characterization of Silicone Oil

The silicone oil used in this study was medical-grade silicone oil with a viscosity of 1,000 centistokes (cSt), sourced from Bausch & Lomb, Incorporated (Industrial Park, Cork Road, Waterford, Ireland). Silicone oil is a colorless and transparent substance with a refractive index of 1.4, similar to that of the vitreous body, which ensures it does not interfere with light transmission. Before use, the silicone oil was stored at room temperature in a sterile environment to maintain its physicochemical properties. During surgery, the silicone oil was prepared according to standard ophthalmic procedures, ensuring sterility and correct viscosity for intraocular application.

Patients

Patients who underwent vitrectomy and silicone oil filling at our facility between 2018 and 2021 were retrospectively reviewed. Axial length measurements were obtained using the IOLMaster 500 (Carl Zeiss Meditec AG, Jena, Germany). The Haigis formula was utilized on the IOLMaster device to calculate the intraocular lens (IOL) power, which is particularly suitable for eyes with high myopia due to its accuracy in long axial lengths. The study included 432 eyes from individuals with high myopia, each having a preoperative axial length greater than 26 mm. Out of these, 136 eyes were excluded from the study for various reasons. Given the heterogeneity of our study population, which included patients with diverse underlying conditions such as diabetic retinopathy, rhegmatogenous retinal detachment, ocular contusion, and penetrating ocular injuries, it is recognized that these conditions may have varied effects on the pathogenesis of "OH" following silicone oil filling. While the analysis primarily focused on overarching risk factors for "OH", the influence of specific underlying diseases on postoperative "OH" incidence was not individually evaluated in this study. Future research should consider stratifying subjects based on their underlying conditions to more precisely assess their individual contributions to "OH" development.

- 56 eyes did not return for postoperative follow-up.
- 21 eyes had primary glaucoma before surgery.
- 14 eyes developed bullous keratopathy due to silicone oil emulsification, which made intraocular pressure measurement with a tonometer impossible.

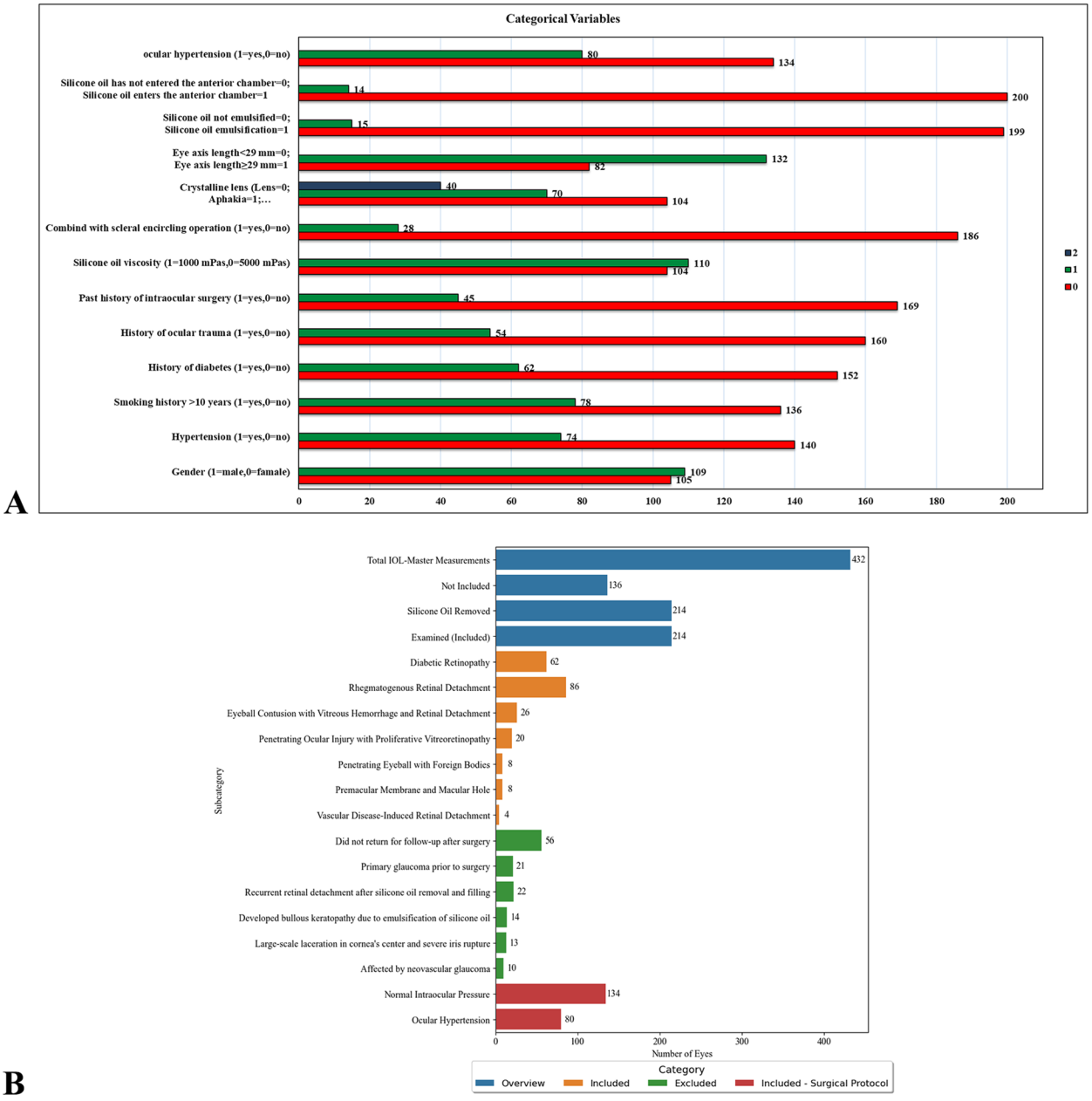
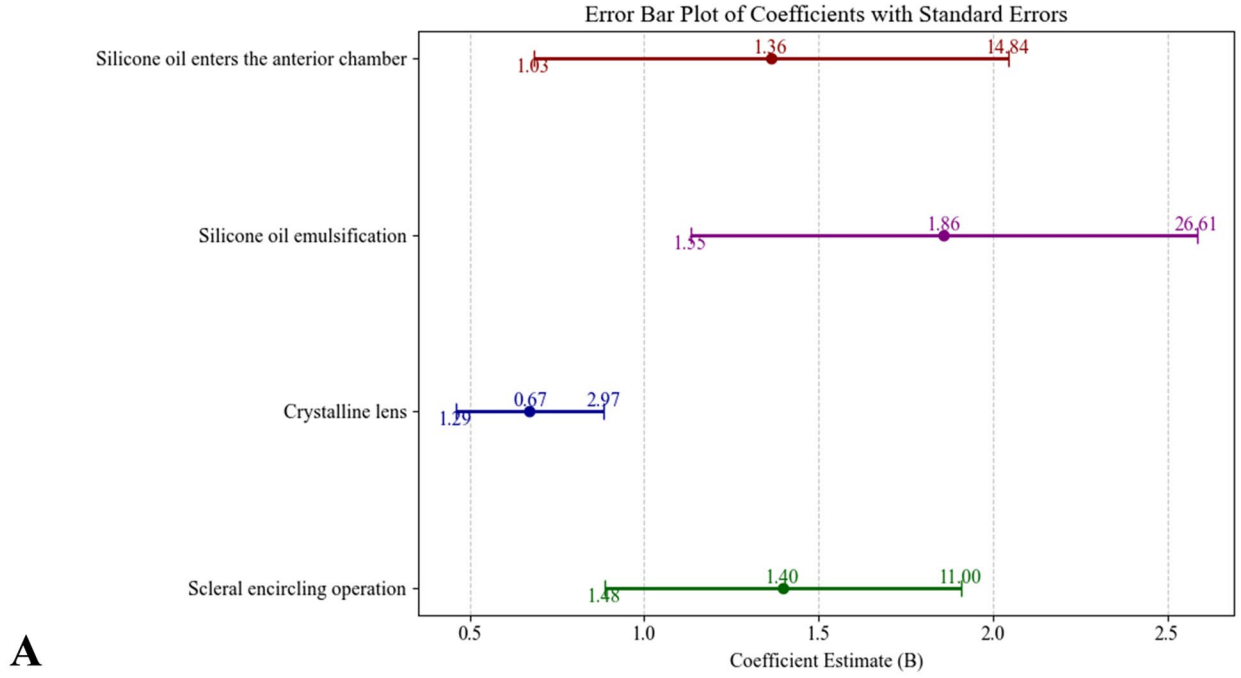


Fig. 1 Patients data and categorical variables. **A** This bar chart provides a detailed breakdown of patients with different eye diseases and whether they were included in the research. The chart outlines specific disorders such as 'diabetic retinopathy' and 'recurrent retinal detachment' as inclusion criteria for the research, while excluding 56 individuals that did not attend follow-up appointments. **B** This bar chart systematically examines how the presence or absence of categorical clinical factors related to the occurrence of ocular hypertension. The chart compares the frequency distribution of counts with clinical variables like 'silicone oil emulsification' and 'past history of intraocular surgery' in the study population, clearly distinguishing between the affirmative, negative, and unspecified control groups

- 13 eyes had large-scale lacerations in the central cornea and severe iris rupture, resulting in extensive iris loss.
- 10 eyes were affected by neovascular glaucoma.

The remaining 214 eyes were retrospectively examined. They included:

- 62 eyes with diabetic retinopathy,
- 86 eyes with rhegmatogenous retinal detachment,
- 26 eyes with eyeball contusion, vitreous hemorrhage, and retinal detachment,
- 20 eyes with penetrating ocular injuries with proliferative vitreoretinopathy,



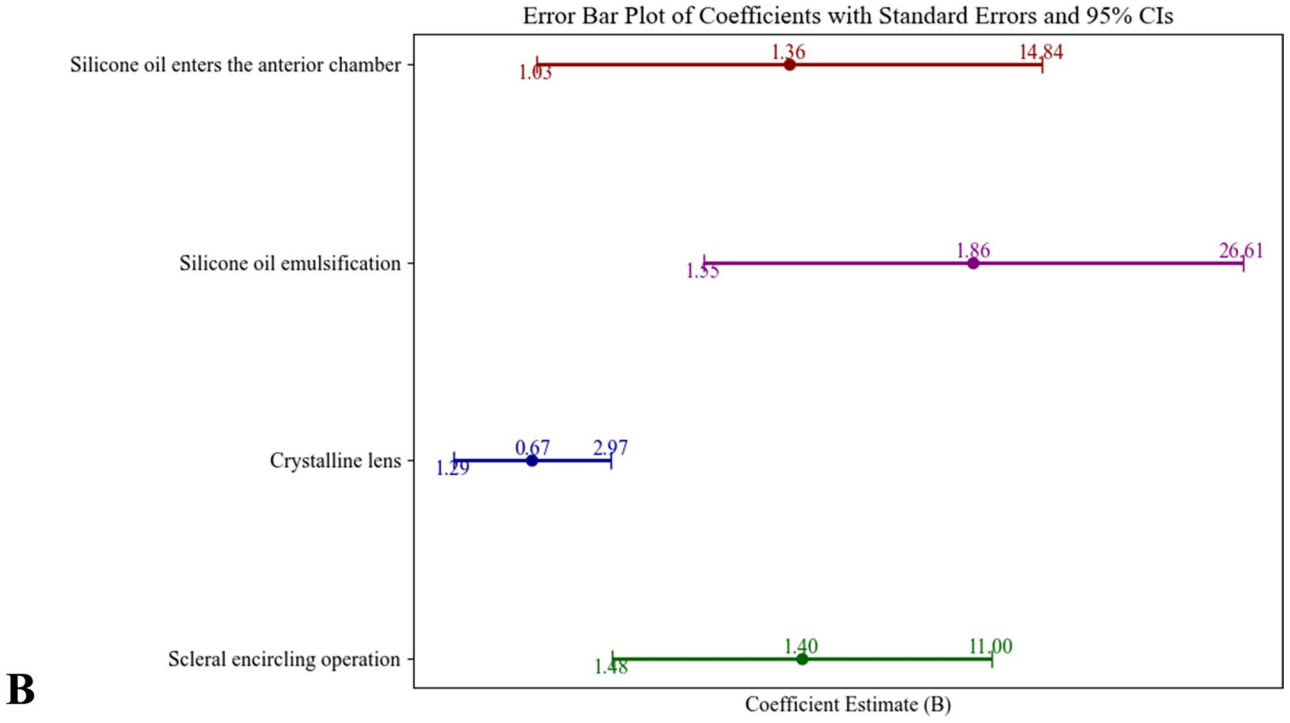


Fig. 2 Error bar plot of coefficients with standard errors and 95% CIs and error bar plot of coefficients with standard errors. **A** This graph displays coefficient estimates together with their corresponding standard errors and 95% confidence ranges, similar to Fig. 6. Confidence intervals (cis) offer a statistical range within which the actual coefficient values are expected to be, with a narrow ci for 'silicone oil enters the anterior chamber' (1.05 to 1.36) indicating a more accurate estimation. **B** The error bar graph displays estimated coefficients of several ocular parameters related to surgical outcomes along the y-axis. Error bars, representing standard errors, enhance the estimated coefficients on the x-axis. The extended error bar for the 'silicone oil emulsification' coefficient, ranging from around 1.5 to 26.61, indicates a notable level of variability, possibly due to measurement inconsistencies or sample diversity

- 8 eyes with penetrating injuries with intraocular foreign bodies,
- 8 eyes with premacular membrane and macular hole,
- 4 eyes with retinal detachment induced by vascular diseases.

The 214 eyes were further divided into two groups based on postoperative intraocular pressure: the normal intraocular pressure (IOP) group ($n=134$) and the ocular hypertension "OH" group ($n=80$). Figure 1A shows a bar chart of eye conditions and surgical outcomes, highlighting 432 IOL Master measurements and notable post-surgical complications. Normal IOP was defined as a range between 10 and 21 mmHg, while "OH" was defined as an IOP reading of greater than 21 mmHg on two consecutive follow-up visits postoperatively. All patients received standardized postoperative care, which included regular follow-up examinations. Intraocular pressure (IOP) was monitored at 1 week, 1 month, 3 months, and 6 months post-surgery using Goldmann applanation tonometry. Additionally, patients were prescribed topical corticosteroids and antibiotics to manage inflammation and prevent infection for the first 4 weeks postoperatively. For eyes that demonstrated signs of elevated IOP during follow-up, adjunctive antiglaucoma medications (e.g., beta-blockers, prostaglandin analogs) were administered as first-line management.

Observational indicators

This study documented the incidence of secondary ocular hypertension "OH" following silicone oil filling. The following variables were analyzed:

- ***Demographic characteristics***: Age, gender, pre-existing conditions (e.g., diabetes, history of intraocular surgery).
- ***Surgical procedures***: Presence of scleral buckling and lens condition (natural lens, aphakia).
- ***Auxiliary examinations***: Axial length measurements, presence of silicone oil in the anterior chamber, and emulsification of silicone oil.
- ***Silicone oil duration***: The length of time silicone oil remained in the eye was recorded and correlated with the development of "OH". The duration was calculated based on the time between the initial silicone oil injection and its removal or the last follow-up visit if the oil was not removed.

Statistical analyses

Data analysis was conducted using Microsoft Excel and Python (version 3.12.3). The dataset was processed using the Pandas library to ensure data integrity and correct formatting. Binary logistic regression analysis, performed with the Statsmodels library, identified significant predictors of secondary ocular hypertension "OH". Exploratory analyses, including descriptive statistics and chi-square tests, were conducted in Excel to provide an overview of the data. The validity of the logistic regression models was assessed using the Hosmer-Lemeshow test to confirm goodness-of-fit. Single-factor analysis was executed using the Wald Test to evaluate the significance of individual predictors [15]. Additionally, multivariate analysis was performed using the Hosmer-Lemeshow test [16] to ensure a thorough assessment of interactions between variables. All statistical tests were two-tailed, with a significance level set at $p<0.05$. These analyses aimed to determine key risk factors associated with "OH" following silicone oil filling.

Results

Predictive factors for ocular hypertension with silicone oil

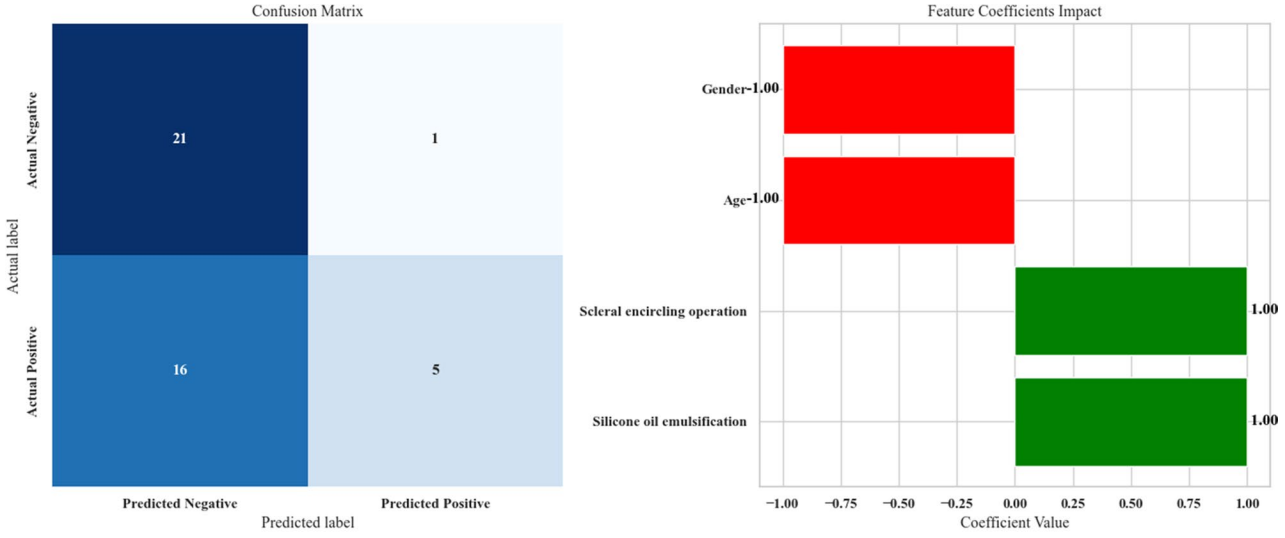
The results presented in Fig. 1B indicate that 80 patients in the study group developed ocular hypertension, with silicone oil presence in the anterior chamber being a significant characteristic associated with this condition. The wide confidence interval seen in Fig. 2A suggests substantial variability in the effects of silicone oil emulsification, which likely contributes to the onset of ocular hypertension, as shown in Fig. 2B. Furthermore, the odds ratios outlined in Table 1 emphasize key risk factors for ocular hypertension, including silicone oil emulsification (OR=6.419) and the scleral encircling procedure (OR=4.042).

The logistic regression model used for predicting ocular hypertension demonstrated an accuracy of 60.47%. The confusion matrix revealed 21 true negatives and 5 true positives, indicating the model's strong performance in identifying negative cases. The model achieved high precision for detecting ocular hypertension, with a value of 0.83, but exhibited a lower recall of 0.24, reflecting its limitations in capturing all positive cases. The F1-scores further highlighted this disparity, with 0.71 for negative predictions and 0.37 for positive predictions, indicating that the model performed better in predicting the absence of ocular hypertension. A heatmap of the

Table 1 Multivariate Logistic regression model results

Items	B	S.E	Wals	Sig.	Exp (B)	95%CIlower limit	95%CI, upper limit
Scleral encircling operation	1.397	0.511	7.470	0.006	4.042	1.485	11.004
Crystalline lens	0.672	0.213	9.952	0.002	1.959	1.290	2.974
Silicone oil emulsification	1.859	0.726	6.565	0.010	6.419	1.548	26.613
Silicone oil enters the anterior chamber	1.364	0.680	4.023	0.045	3.913	1.032	14.839
Constant	-1.970	9.914	0.039	0.842	0.139	0.000	38309799.078

Note: Exp (B) is the OR value, OR<1 is a protective factor, and OR>1 is a risk factor



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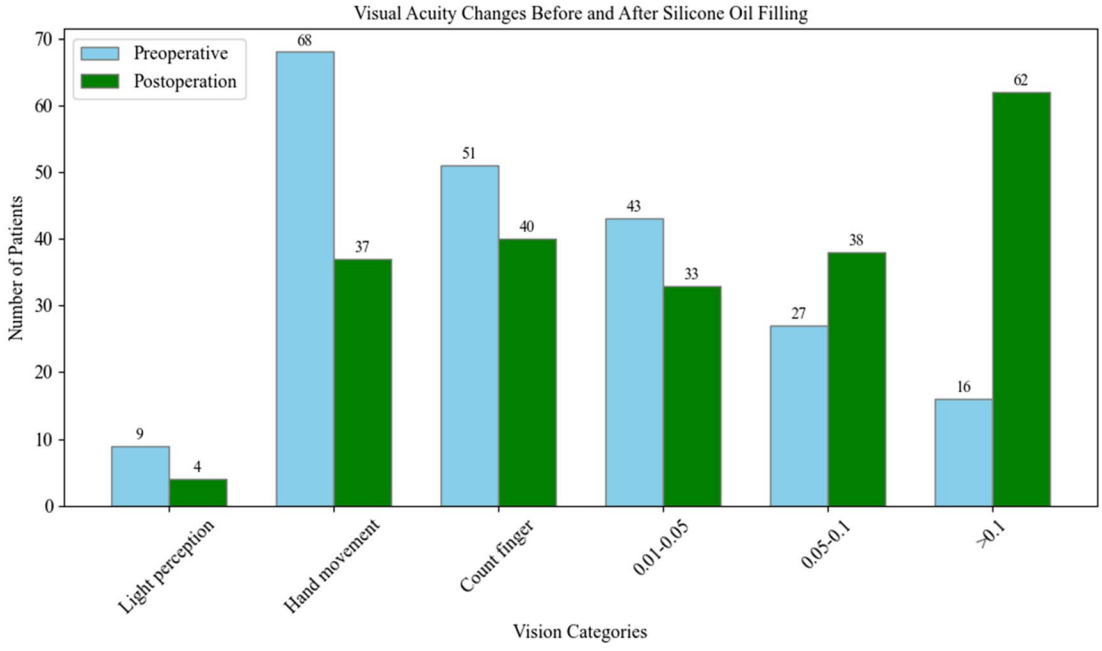


B

Fig. 3 A confusion matrix heatmap of actual negative vs. Actual positive and graphical representation of visual acuity changes before and after silicone oil filling. **A** A confusion matrix heatmap for a medical diagnostic test. It effectively distinguishes the outcomes of actual negative vs. Actual positive against predicted negative and predicted positive. The annotations within each cell—true negatives (21), false positives (1), false negatives (16), and true positives (5)—are clearly marked, making it straightforward to interpret the model's performance. The color gradient from blue to red highlights the range from lower to higher values, respectively, facilitating an immediate understanding of the test's accuracy in predicting ocular hypertension. The overall design is clean and professional, making it suitable for inclusion in medical research presentations, where clarity and precision are paramount. **B** This visual chart compares the visual acuity of patients prior to and subsequent to silicone oil tamponade, a prevalent therapeutic approach for retinal detachment. The preoperative visual acuity categories range from 'light perception' to '>0.1'. Significant postoperative enhancements in visual acuity were observed, as indicated by the increase in the number of patients falling within the '>0.1' category from 27 to 62. This finding suggests that the silicone oil intervention had a positive impact

Table 2 Visual acuity changes before and after silicone oil filling (n)

Vision	Light perception	Hand movement	Count finger	0.01–0.05	0.05–0.1	> 0.1
Pre operative	9	68	51	43	27	16
Post operation	4	37	40	33	38	62

confusion matrix, comparing actual negatives and positives, is shown in Fig. 3A.

Vision changes before and after silicone oil filling

The Table 2 illustrates the contrast in visual acuity classifications before and after a surgical procedure. Significantly, there is a rise in the number of patients with postoperative eyesight beyond 0.1, indicating an enhancement in visual results after the surgery. In contrast, the postoperative period results in a drop in the frequency of patients experiencing lower visual acuity categories, such as light perception and hand movement. This suggests a reduction in the prevalence of more severe visual impairments. See Fig. 3B for graphical representation of Visual acuity changes before and after silicone oil filling.

Temporal dynamics of Ocular Hypertension Post-surgery

The temporal analysis of ocular hypertension "OH" incidence post-surgery reveals specific trends. Initially, 14 cases of "OH" were observed within the first week following the operation. This number increased to 20 cases in the period extending from one week to one-month post-surgery. Thereafter, a noticeable decline in the occurrence of OH was recorded, with the lowest incidence observed between three and six months postoperatively. This timeframe indicates a lower likelihood of "OH" onset as the eye stabilizes over time, rather than any seasonal variation. This data underscores the variable timing of "OH" onset after surgical interventions, highlighting the importance of continuous monitoring over different postoperative intervals. A detailed visual representation of these trends is provided in Fig. 4A.

Axial length variations before and after silicone oil removal

Figure 4B presents the variations in axial eye length at three specific time points: pre-vitrectomy, one-month post-silicone oil removal, and pre-subsequent vitrectomy. The measured axial lengths were 28.31 mm (±0.82 mm), 29.21 mm (±0.85 mm), and 29.11 mm (±0.79 mm), respectively. A significant increase in axial length from 28.31 mm to 29.21 mm was observed after the insertion of silicone oil and before its removal ($t=11.15$, $P<0.001$). However, it is acknowledged that this difference in AL may also be influenced by other factors, such as the use of different measurement methods (e.g., ultrasound versus optical biometry) and the status of the retina before and after vitrectomy, rather than IOP alone. These variables may contribute to variability in AL measurements and should be considered in interpreting postoperative AL changes. However, there was no statistically significant difference in axial length between the pre-vitrectomy measurement and the one-month post-silicone oil removal measurement, indicating that the eye's axial length tends to stabilize after silicone oil removal, returning close to its original state before the first vitrectomy. This suggests that silicone oil has a transient effect on axial eye expansion, with minimal long-term structural alterations following its removal.

Ocular hypertension after Silicone Oil Filling

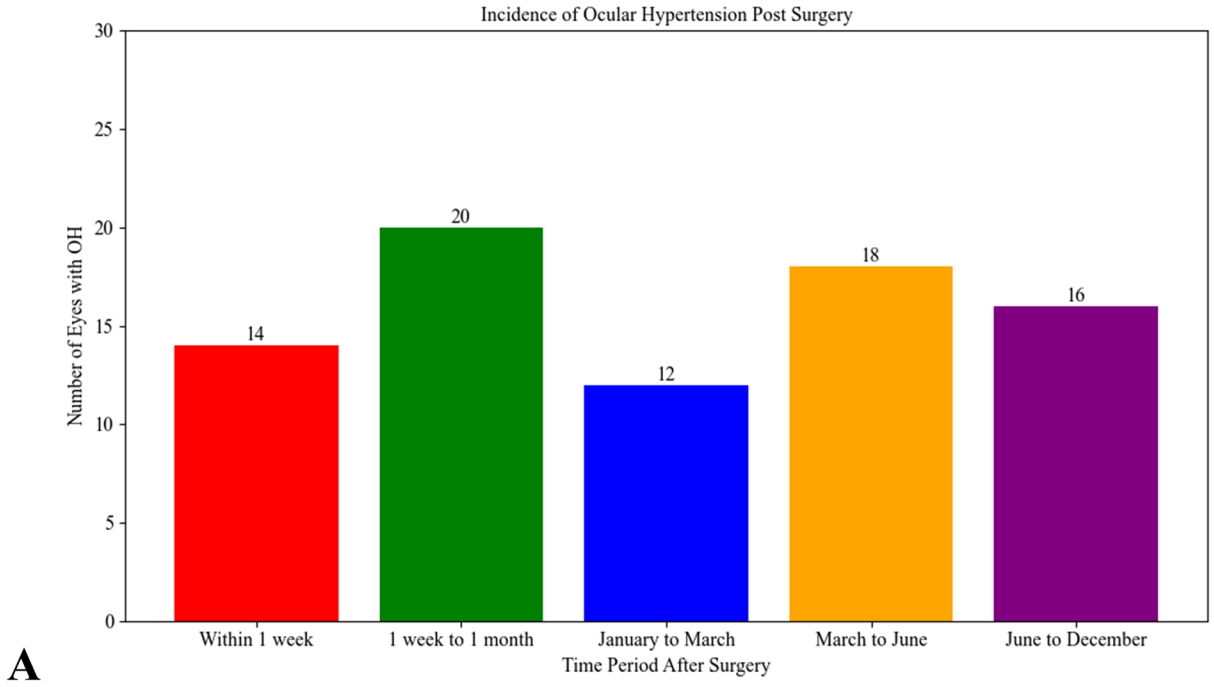
Single factor analysis (Wald Test)

Table 3; Fig. 5A show a clear association between specific surgical variables and an increased risk of ocular hypertension. Aphakia was linked to a higher incidence of ocular hypertension (57.14%) compared to the presence of a natural lens (21.15%) or an intraocular lens (45.00%). Additionally, patients who underwent a scleral encircling surgery had a higher prevalence of hypertension (64.28%) compared to those who did not have the procedure (33.33%) ($P=0.006273$). These findings underscore the crucial role that surgical considerations play in the development of ocular hypertension following silicone oil filling surgery.

Multivariate Analysis (Hosmer-Lemeshow Test)

The Wald Test, as outlined in Table 3, emphasizes the significant impact of surgical variables on the development of postoperative ocular hypertension. Aphakia was significantly associated with a high incidence of ocular hypertension, affecting 57.14% of individuals with this condition. In contrast, the incidence was 21.15% for patients with natural lenses and 45.00% for those with intraocular lenses. Furthermore, patients who underwent a scleral encircling procedure had a markedly higher likelihood of developing hypertension (64.28%) compared to those who did not have the operation (33.33%) ($P=0.006273$). Figure 5B illustrates the varying effects of different factors on patients with normal intraocular pressure compared to those with ocular hypertension, highlighting the increased risk associated with certain surgical procedures after silicone oil filling.

The independent variables detailed in Table 4 provide crucial insights into the factors influencing postoperative ocular hypertension following silicone oil filling surgery. These variables include the scleral encircling operation (X1), crystalline lens condition (X2), silicone oil emulsification (X3), and silicone oil penetration into the anterior chamber (X4). Each variable is assigned specific values to indicate their presence or absence. For example, X1 distinguishes between patients who did not undergo a scleral encircling operation (0) and those who did (1). Similarly, X2 categorizes lens condition into three groups: normal lens (0), aphakia (1), and intraocular lens (2). X3 differentiates between patients with non-emulsified silicone oil (0) and those with emulsified silicone oil (1), while X4 identifies whether silicone oil has entered the anterior chamber (1) or not (0).



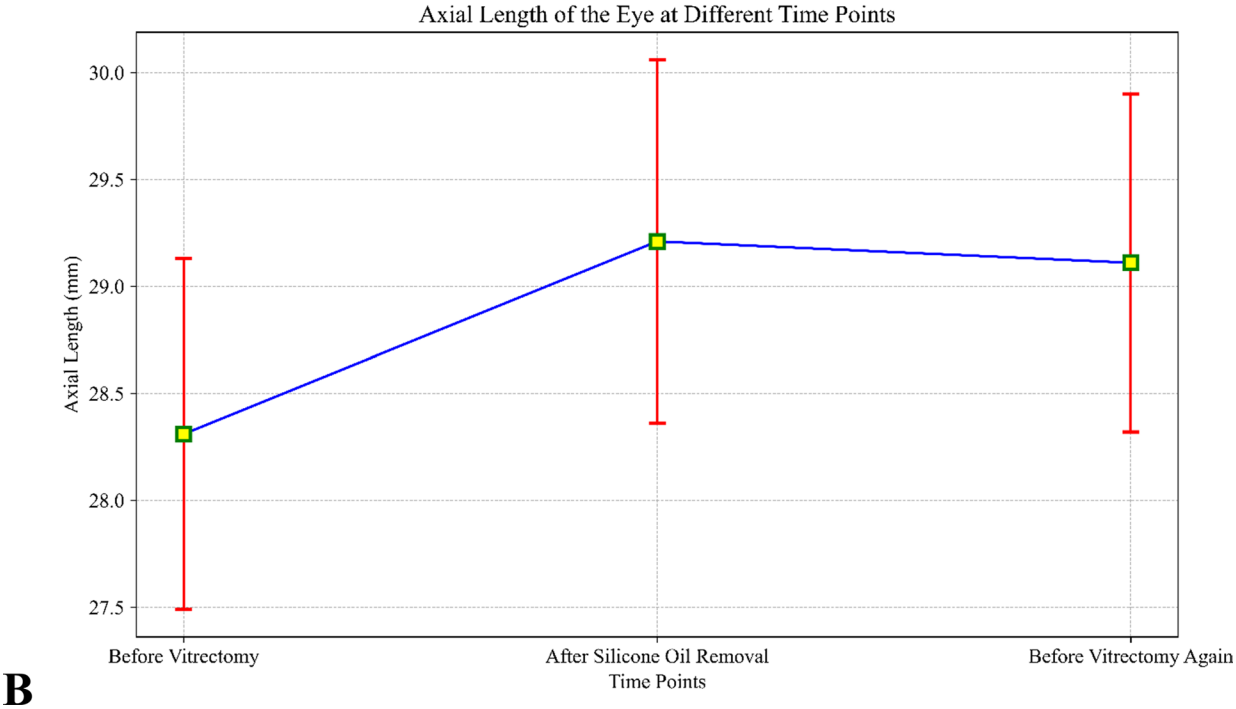


Fig. 4 Incidence of ocular hypertension post surgery and axial length of the eye at different time points. **A** The temporal progression of ocular hypertension subsequent to surgical intervention is categorized using a bar chart. In contrast to the categorical x-axis, which delineates the postoperative timeline, the y-axis measures the incidence in the views of the patients. A noteworthy observation is the twenty cases that occurred at the peak incidence between one week and one month; this interval may indicate a period of increased risk for the development of postoperative hypertension. **B** The graph presents a detailed comparison of the axial length of the eye measured at three critical time points in relation to vitrectomy and silicone oil management: Before vitrectomy, after silicone oil removal, and before vitrectomy once again. The axial lengths recorded were 28.31 mm (±0.82 mm), 29.21 mm (±0.85 mm), and 29.11 mm (±0.79 mm) for each respective time point

Table 3 Single factor analysis

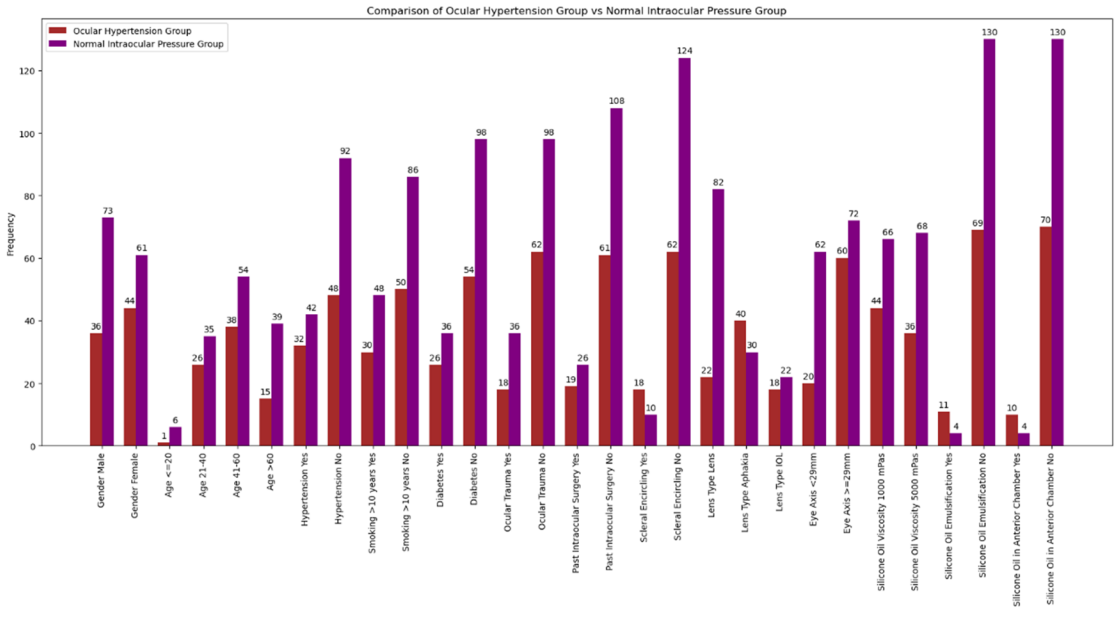
Factors		Ocular hypertension group ($n=80$)	Normal intraocular pressure group ($n=134$)	Chi-square value	*P* value
Gender	Male	36 (33.03)	73 (66.97)	1.1996772	0.230264729
	Female	44 (41.90)	61 (58.10)		
Age (year)	≤ 20	1 (14.28)	6 (85.72)	1.1996772	0.230264729
	21–40	26 (42.62)	35 (57.38)		
	41–60	38 (41.30)	54 (58.70)		
	> 60	15 (27.78)	39 (72.22)		
Hypertension	Yes	32 (43.24)	42 (56.76)	1.1996772	0.230264729
	No	48 (34.28)	92 (65.72)		
Smoking history > 10 years	Yes	30 (38.46)	48 (61.54)	0.4132525	0.679421605
	No	50 (36.76)	86 (63.24)		
History of diabetes	Yes	26 (41.93)	36 (58.07)	1.3594392	0.17400745
	No	54 (33.53)	98 (66.47)		
History of ocular trauma	Yes	18 (33.33)	36 (66.67)	-0.7589368	0.447890366
	No	62 (38.75)	98 (61.25)		
Past history of intraocular surgery	Yes	19 (42.22)	26 (57.78)	0.9546815	0.339738794
	No	61 (36.09)	108 (63.91)		
Combined with scleral encircling operation	Yes	18 (64.28)	10 (35.72)	2.7331730	0.006273
	No	62 (33.33)	124 (66.67)		
Crystalline lens	Lens	22 (21.15)	82 (78.85)	3.1547040	0.001607
	Aphakia	40 (57.14)	30 (42.86)		
	Intraocular lens	18 (45.00)	22 (55.00)		
Eye axis length	< 29 mm	20 (24.39)	62 (75.61)	1.7149690	0.086351
	≥ 29 mm	60 (45.45)	72 (54.55)		
Silicone oil viscosity	1000 mPas	44 (40.00)	66 (60.00)	0.7790680	0.435939
	5000 mPas	36 (34.62)	68 (65.38)		
Silicone oil emulsification	Yes	11 (73.33)	4 (26.67)	2.5621983	0.01040119
	No	69 (34.67)	130 (65.33)		
Silicone oil enters the anterior chamber	Yes	10 (71.42)	4 (28.58)	2.0057430	0.044884
	No	70 (35.00)	130 (65.00)		

Discussion

Silicone oil has been extensively used in vitreoretinal surgery as a vitreous substitute due to its excellent light transmission and chemical stability [17]. However, its application is not without complications, as ocular hypertension "OH" frequently occurs following silicone oil injection [18]. In this study, "OH" was observed in 80 out of 214 eyes, resulting in an incidence rate of 37.38%. Elevated intraocular pressure (IOP) can cause significant optic nerve damage, potentially leading to irreversible visual impairment if not managed promptly and effectively [19]. Tode [20] reported that, among 15 patients with macular hole-related retinal detachment treated using silicone oil tamponade, 3 patients experienced persistent vision impairment. This impairment was likely attributable to the weakening of the inner retinal layers. Similarly, Scheerlinck [21] found that 30% of patients undergoing vitrectomy with silicone oil filling for primary rhegmatogenous retinal detachment experienced a decline in visual acuity, which appeared to be related to the duration of silicone oil filling.

Several studies have sought to identify the risk factors for secondary "OH" following silicone oil injection, though results have varied. The present study compared the clinical data of patients who developed "OH" after vitrectomy with silicone oil injection to those who maintained normal intraocular pressure postoperatively. The primary goal was to elucidate the underlying causes of "OH", reduce the incidence of this complication, and thereby improve the outcomes of vitreoretinal surgeries.

One of the significant observations in this study was an increase in axial length postoperatively. Preoperative axial length was recorded at (28.31 ± 0.82) mm, which increased to (29.21 ± 0.85) mm after silicone oil injection. This finding suggests that the injection of silicone oil into highly myopic eyes could contribute to an increase in axial length. Although it remains unclear if this change directly influences surgical complications or postoperative visual outcomes, further research is warranted. Out of the 214 eyes treated, 80 experienced elevated intraocular pressure, aligning with previous research findings [19].



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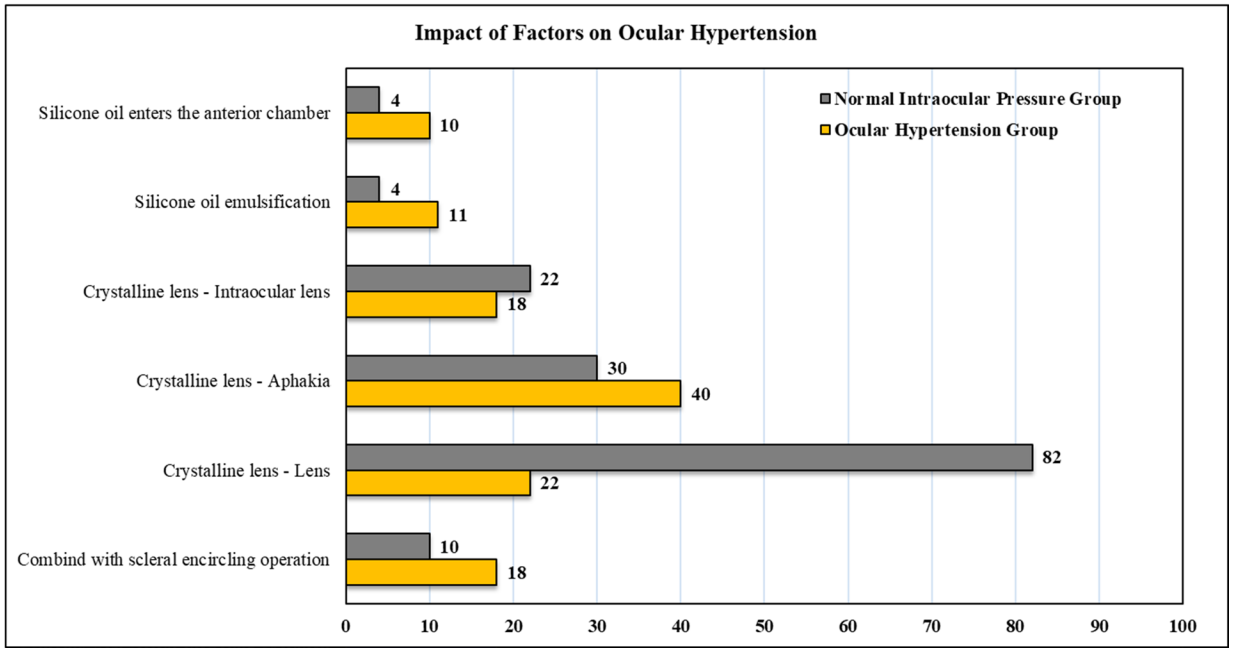

B

Fig. 5 Comparison of ocular hypertension group vs. normal intraocular pressure group and impact of factors on ocular hypertension. **A** A bar chart contrasts the incidence of ocular hypertension to that of a control group with normal intraocular pressure across a range of demographic and clinical parameters in a systematic manner. The patient count within each category is represented by a bar; individuals with ocular hypertension are colored purple, while those with normotension are depicted in red. The data illustrates a significant incidence of ocular hypertension among cohorts that also have systemic comorbidities, including diabetes (indexed at 152 for hypertension, 78 for smoking history exceeding ten years, and 62 for diabetes, respectively). **B** The graph illustrates how several clinical conditions affect the occurrence of ocular hypertension compared to a group with normal intraocular pressure. The abscissa represents the frequency of occurrences, whereas the ordinate categorizes therapeutic procedures and conditions. The factor 'combined with scleral encircling procedure' showed a significant difference, with 82 occurrences in the hypertension group and 22 in the normotensive group, indicating a possible link to increased eye pressure

Multifactorial analysis revealed several significant risk factors contributing to the development of "OH" after silicone oil injection. However, we acknowledge that the study did not include a detailed examination of the angle status and other specific features of the anterior segment over the postoperative period. These anatomical factors could play a crucial role in understanding the causative mechanisms of "OH", especially as angle narrowing or

Table 4 Independent variables

Factors	Variable	Assignment
Scleral encircling operation	X1	Not combined with Scleral encircling operation = 0
		Combined Scleral encircling operation = 1
Crystalline lens	X2	Lens = 0
		Aphakia = 1
		Intraocular lens = 2
Silicone oil emulsification	X3	Silicone oil not emulsified = 0
		Silicone oil emulsification = 1
Silicone oil enters the anterior chamber	X4	Silicone oil has not entered the anterior chamber = 0
		Silicone oil enters the anterior chamber = 1

closure can significantly influence IOP. Future research should incorporate detailed anterior segment imaging and evaluation to provide a more comprehensive interpretation of the causality of "OH" following silicone oil filling. These included the combination of silicone oil filling with scleral encircling surgery, aphakia, an axial length of 29 mm or greater, silicone oil emulsification, and the entry of silicone oil into the anterior chamber. It is acknowledged that certain factors, such as silicone oil in the AC, oil emulsification, and aphakia status, have been well-documented in prior studies as contributors to "OH" risk. However, our study reaffirms these known associations in a population with high myopia and highlights additional insights, particularly regarding the combined impact of these risk factors on postoperative "OH". By quantifying their predictive value, this study contributes a nuanced understanding of risk stratification for "OH" following silicone oil filling. The odds ratios (OR) for these factors were 3.478, 1.945, 2.461, 5.387, and 4.151, respectively. These findings indicate a substantial association between these factors and the onset of "OH", providing important considerations for clinicians during surgical planning and postoperative care.

Patients undergoing vitrectomy combined with scleral encircling showed a higher frequency of "OH" than those who did not undergo the encircling procedure. This may result from several factors, including the application of a tight external scleral ring, elevated surgical crest positioning, or improper placement, all of which can restrict normal blood flow and cause ciliary body swelling. Moreover, reducing the scleral diameter by silicone oil pressure or cerclage can decrease overall eye volume, leading to the forward displacement of the lens-iris diaphragm. This displacement narrows the anterior chamber and may induce secondary angle-closure glaucoma. Thus, the combination of scleral encircling with silicone oil filling significantly elevates the risk of "OH".

Aphakia also emerged as a notable risk factor. Mohalhal [22] observed a postoperative rise in intraocular pressure in pseudophakic eyes, suggesting that "OH" is more prevalent in patients lacking natural lenses compared to those with intact lenses. The intraocular lens acts as a less effective barrier, increasing the likelihood of silicone oil migration into the anterior chamber via the suspensory ligament. Consequently, patients with aphakia or those equipped with intraocular lenses face an increased risk of developing "OH" after silicone oil injection.

Highly myopic eyes, characterized by a significantly longer axial length than normal eyes [23], present another risk factor. The enlarged vitreous cavity in these eyes necessitates a greater volume of silicone oil for filling, which increases buoyancy within the cavity. This increased buoyancy exerts tension on the lens-iris diaphragm, resulting in its forward displacement, narrowing the chamber angle, and elevating intraocular pressure. Additionally, the inherently relaxed lens suspension in myopic eyes further compromises lens stability, making a longer axial length a key risk factor for "OH" following silicone oil injection.

Silicone oil emulsification is yet another contributing factor to "OH". Prolonged retention of silicone oil can lead to its emulsification, forming droplets that migrate to the chamber angles, obstruct the trabecular meshwork, and hinder aqueous humor outflow, thereby causing "OH" [24]. Furthermore, silicone oil that enters the anterior chamber may block the pupil and obstruct the chamber angle, disrupting the normal circulation of aqueous humor and resulting in an increase in intraocular pressure [25].

This study provides valuable insights into the mechanisms underlying "OH" development following silicone oil filling. Initial assessments of demographic factors such as age and gender showed no statistically significant differences in "OH" incidence rates. Additionally, it is acknowledged that postoperative positioning, particularly face-down positioning, was not evaluated in our analysis. Face-down positioning following vitrectomy has been reported to contribute to higher IOP levels, especially during the early postoperative period. Future studies should incorporate postoperative positioning as a variable to better understand its potential impact on the development of "OH" in the context of silicone oil filling, suggesting that these demographic characteristics do not directly influence "OH" pathogenesis. Additionally, a detailed review of patients' medical histories revealed that conditions like diabetes, eye injuries, and previous intraocular surgeries did not significantly impact the risk of developing "OH". This finding challenges the common perception that pre-existing conditions invariably exacerbate postoperative complications associated with "OH".

In this study, a logistic regression model was employed for multivariate analysis to explore the interrelationships among various risk factors while minimizing potential

biases. The model included axial length, silicone oil entry into the anterior chamber, crystalline lens status, and scleral encircling procedures as variables, with intraocular pressure as the dependent variable. The analysis successfully identified key risk factors that significantly elevated the likelihood of "OH" in patients. The model's predictive accuracy was validated using the Hosmer-Lemeshow test, reinforcing its reliability.

Despite its contributions, this study has certain limitations. The retrospective design may introduce selection and data collection biases, potentially affecting the generalizability of the results. Furthermore, while the association between "OH", aphakia, axial length, and silicone oil emulsification was established, it does not imply a direct causal relationship. Future research should include prospective studies, randomized clinical trials, and larger sample sizes to confirm these associations and establish causality.

In conclusion, this study underscores the importance of individualized patient assessments and meticulous preoperative planning for vitreoretinal procedures. Precision in surgical techniques and diligent postoperative care are crucial for managing "OH", particularly in patients with high myopia who undergo silicone oil filling. Further research focused on refining surgical methods and enhancing postoperative care can potentially reduce the incidence of "OH", thereby improving long-term patient outcomes in vitreoretinal surgery.

Conclusion

The findings of this study emphasize a strong correlation between ocular hypertension "OH" development and changes in the anterior segment anatomy, as well as aqueous humor flow dynamics, particularly in aphakic eyes post-silicone oil filling. Key risk factors, such as scleral buckling, aphakic status, silicone oil emulsification, and penetration into the anterior chamber, were identified as significant predictors for "OH" occurrence. These insights underscore the need for thorough preoperative assessments and tailored postoperative care in patients with high myopia undergoing silicone oil filling, to mitigate the risk of "OH" and enhance overall surgical outcomes.

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Author contributions
Xiaodan Lin, and Shenghui Feng were responsible to the operation and contributed signifcantly to analysis and manuscript preparation; Chunmei Chen, and Yadan Xiong, performed the data analyses; Na Li and Ling Tong helped perform the analysis and contribute figures output. The author(s) read and approved the fnal manuscript.

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Data availability
The datasets used and analyzed in the current study are available from the corresponding author on demand.

Declarations

Ethics approval and consent to participate
The study was carried out in accordance with the Helsinki Declaration. Informed consent was obtained from all patients. This study protocol was reviewed and approved by the Ethics Committee of Chongqing Bright Eye Hospital, Chongqin, PR. China.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Others
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