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Analysis of risk factors for vitreous hemorrhage and recurrent hemorrhage after vitrectomy in patients with diabetic retinopathy

Shuwen Lu[1,6*], Haoyu Li[2], Chao Ma[3] and Xian Li[4,5]

Abstract

Purpose To investigate the risk factors associated with recurrent hemorrhage following vitrectomy surgical intervention for diabetic retinopathy (DR).

Methods A retrospective analysis was conducted on 579 eyes diagnosed with DR necessitating surgical intervention. These cases were categorized into two groups: recurrent hemorrhage and non-recurrent hemorrhage. Comparative, random forest (RF), and regression analyses were subsequently performed to evaluate variables pertaining to patients' demographic information, clinical examination and blood test results, treatment approaches, lifestyle habits, and overall health status.

Results This study compared patients with recurrent and non-recurrent hemorrhages, revealing significant differences in factors such as endodiathermy, anticoagulant use, cerebrovascular diseases, smoking status, glycosylated hemoglobin levels and BMI. Patients with no recurrent hemorrhage have faster vision recovery. The univariable logistic regression analysis indicated that cerebrovascular disease (OR = 7.87, $P < 0.001$), anticoagulant use (OR = 16.72, $P < 0.001$), and elevated glycated hemoglobin levels (OR = 21.22, $P < 0.001$) exhibited strong associations with recurrent hemorrhage. The multivariable logistic regression analysis indicated that recurrent hemorrhage risk factors include anticoagulant use (OR = 120.77, $P = 0.020$) and glycated hemoglobin levels (OR = 18.41, $P = 0.001$).

Conclusions Recurrent postoperative hemorrhage is influenced by several factors, notably the use of intraoperative endodiathermy, adjustments in ocular therapy, and management of the patient's systemic condition. In clinical practice, careful consideration of these factors is essential to mitigate postoperative hemorrhage in patients.

Keywords Diabetic retinopathy, Vitreous hemorrhage, Recurrent hemorrhage, Endodiathermy, Risk factors

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Introduction

Diabetic retinopathy (DR) is one of the major microvascular complications in diabetic patients with poor glycemic control. Extraocular factors contributing to the risk and progression of diabetic retinopathy include inadequate glycemic control, hypertension, dyslipidemia, the duration of diabetes mellitus, pregnancy, and genetic predispositions [1]. The current main treatment options for DR include retinal laser photocoagulation, intravitreal injection of anti-vascular endothelial growth factor and vitrectomy [2, 3]. Vitrectomy is considered the first-line treatment for vision loss due to vitreous hemorrhage (VH) or tractional retinal detachment in stage V or VI DR [4–6]. VH is common in patients with proliferative diabetic retinopathy (PDR) and can lead to severe vision loss [7]. Anti- vascular endothelial growth factor (VEGF) agents are widely utilized therapeutic interventions for DR. Ranibizumab, a recombinant fragment of a humanized monoclonal antibody targeting VEGF, received approval from the United States Food and Drug Administration in 2017 for the treatment of all stages of diabetic retinopathy [8]. Aflibercept, a recombinant fusion protein comprising the binding domains of human VEGF receptors 1 and 2, currently demonstrates significant efficacy in the management of diabetic retinopathy [9]. Despite treatment of PDR with total retinal photocoagulation (PRP) or intravitreal anti-vascular endothelial growth factor, almost half of the eyes in the Diabetic Retinopathy Clinical Research Retina Network Protocol S developed VH during the 5-year follow-up period [10]. Therefore, patients with unresorbable VH or organized blood will require vitrectomy. VH after diabetic vitrectomy has been reported in 12–63% of cases, and it can affect the recovery of vision and cause anxiety and decreased confidence in treatment [11–14]. Postoperative fibrovascular proliferation, lower extremity amputation, and the administration of antihypertensive medications are significant contributors to the incidence of VH following surgical procedures [15]. Post-vitrectomy VH may occur after the first few weeks or months after surgery, although only a minority of patients require additional surgical treatment, and how to reduce post-operative VH in patients is now an important issue to be addressed.

In terms of treatment, the patients with stage IV DR with severe visual impact is based on vitrectomy. The relationship between various preoperative and postoperative parameters and the occurrence and regression of VH remains currently undetermined. Therefore, understanding the clinical risk factors of DR patients who need vitrectomy treatment and exploring the changes in visual acuity, intraocular pressure, and postoperative recurrent hemorrhage before and after vitrectomy treatment in DR patients with different DR stages will help us to understand the factors of disease progression, to control the progression of the disease or even intervene in advance, and to reduce the incidence of recurrent hemorrhage to protect the patient's vision.

In this study, we retrospectively analyzed DR in patients with type 2 diabetes mellitus who required vitrectomy to identify risk factors associated with disease progression and to assess factors influencing preoperative and postoperative visual acuity, intraocular pressure, and recurrent VH.

Methods

Patients

Retrospective analysis of 579 eye of 579 patients who underwent primary pars plana vitrectomy (PPV) for active PDR in our hospital from January 1, 2019 to December 31, 2023 in our hospital. Patients who achieved PDR and were treated with vitrectomy were our study population [16]. In addition, in order to compare the differences between the different stages (Fig. 1), the patients included were classified into the following stages of PDR using the six-stage clinical classification of DR proposed by Scott [17]: Stage IV, with the presence of neovascularization or VH; Stage V, with the presence of neovascularization and fibroplasia; and Stage VI, with the presence of neovascularization and fibroplasia complicating retinal detachment. Inclusion criteria: fundus examination found active fibrovascular hyperplasia with VH or preretinal hemorrhage or combined with traction retinal detachment. Exclusion criteria: (1) Patients diagnosed with rhegmatogenous retinal detachment at the time of VH or patients with neovascular glaucoma requiring anti-glaucoma surgical treatment; (2) History of blood diseases related to abnormal coagulation; (3) Combined with other ocular or systemic inflammatory diseases. Informed consent was obtained from each patient before surgery.

The preoperative evaluation for the potential integration of cataract surgery with vitrectomy involves making three minimally invasive scleral incisions, each positioned 3.5 mm from the edge of the angle membrane. These incisions accommodate the infusion cannula, illumination fiber, and vitrectomy probe. Following the excision of the opaque vitreous body and induction of posterior vitreous detachment, the anterior retinal membrane and any hemorrhagic areas are addressed. Hemostasis is achieved through the application of electrocoagulation under direct visualization. Subsequently, various materials are introduced into the vitreous cavity, tailored to the specific condition of the patient's fundus. The injection of anti VEGF drugs is performed one week before vitrectomy.

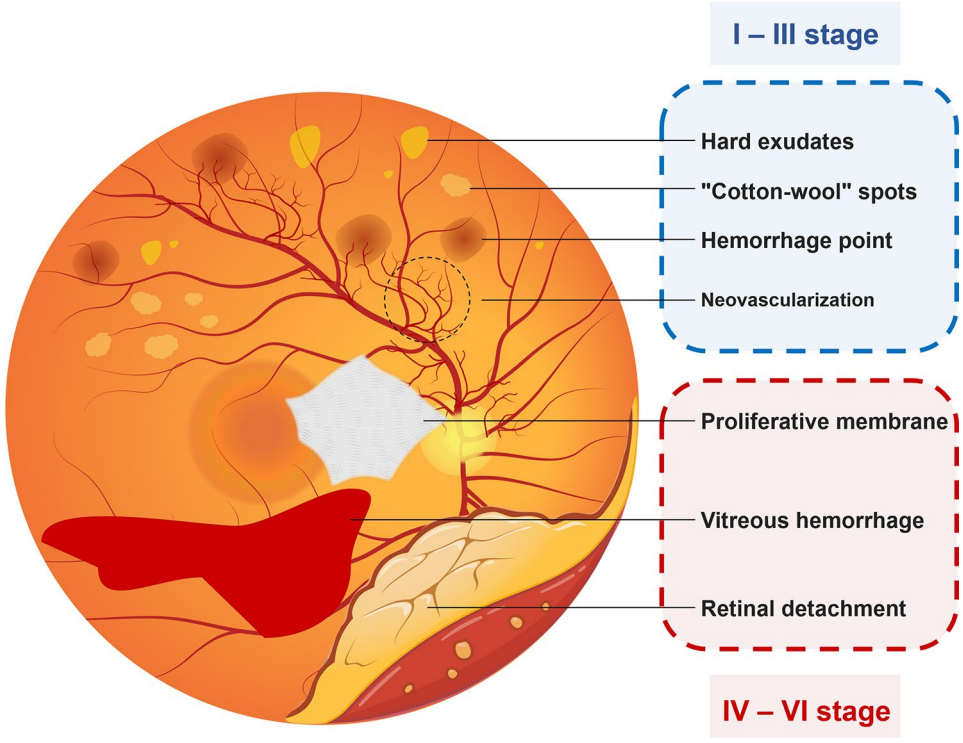

Fig. 1 Fundus characteristics of non-proliferative and proliferative diabetic retinopathy

Observation factors

For preoperative variables, we collected the following parameters: age, gender, body mass index, systolic and diastolic blood pressure, preoperative fasting glucose, glycated hemoglobin (HbA1c), endodiathermy, and whether vitreous cavity injection of anti-VEGF drugs ((ranibizumab 2 mg/0.2 ml, Novartis) or (aflibercept 2 mg/0.2 ml, Bayer)) was performed. We also collected information on diabetes management (oral hypoglycemic agents or insulin use), history of cardiovascular and renal disease, and anticoagulant medication. Surgical variables included whether the lens was removed and whether gas or silicone oil was used during surgery. Postoperatively, patients were observed for the incidence and extent of recurrent VH and for complications such as glaucoma. All patients collected in this study were operated by two surgeons (W.S. and L.L.), and all patients in this study underwent all surgical operations using the 23 g vitrectomy system. The occurrence and severity of recurrent hemorrhage, postoperative best corrected visual acuity, intraocular pressure and complications were evaluated at 3, 15, 45, and 90 days postoperatively. The severity of postoperative hemorrhage was classified as. grade 1. Optic disc and retinal vessels were clearly visible on the ophthalmoscope; grade 2, some retinal vessels were visible; grade 3, unclear optic disc border; and grade 4, no clear optic disc [18]. The patient cohort was stratified into two distinct groups: individuals without recurrent hemorrhage and those with recurrent hemorrhage episodes. Comparative analyses were conducted to evaluate the disparities in each included indicator between these groups, alongside an assessment of variations in visual acuity. Furthermore, multiple logistic regression analysis was employed to identify potential factors associated with recurrent hemorrhage.

Statistical analysis

Statistical analyses were performed using R software (version 4.4.3). Differences between two groups were assessed using the independent sample *t*-test. Random forest (RF) analysis was conducted to identify the most important predictive variables. The optimal number of trees (ntree) and the number of variables randomly sampled at each split (mtry) were determined based on the minimum out-of-bag (OOB) error rate. Variable importance was evaluated according to the Mean Decrease Gini index, and the top-ranking variables were selected for further analysis. Receiver operating characteristic (ROC) curves were generated using the selected variables, and the area under the curve (AUC) was calculated to assess the discriminative ability of the model. Subsequently, univariate and multivariate logistic regression analyses were performed to further evaluate the association between the selected variables and recurrent vitreous hemorrhage. Odds ratios (ORs) and 95% confidence intervals (CIs) were reported for each variable. A

Table 1 Clinical characteristics of study participants

Characteristics	
Sex (male/female)	329/247
Age (years)	
Mean (SD)	55. 7 (11.0)
Range	15–84
BMI (kg/m^2)	
Mean (SD)	25.2 (1.3)
Range	23.0–30.5
Systolic blood pressure (mmHg)	
Mean (SD)	159.2 (16.7)
Range	127.0–199.0
Diastolic blood pressure (mmHg)	
Mean (SD)	96.7 (7.3)
Range	70.0–110.0
Preoperative HbA1c (%)	
Mean (SD)	8.2 (1.2)
Range	6.0–10.9
Recurrent vitreous hemorrhage HbA1c (%)	
Mean (SD)	10.0 (0.6)
Range	7.8–10.9
Preoperative fasting blood sugar (mmol/L)	
Mean (SD)	6.0 (1.2)
Range	3.8–8.0
Duration of diabetes (years)	
Mean (SD)	14.0 (6.5)
Range	1.0–25.0
History of cardiovascular disease (yes/no)	74/502
History of cerebrovascular diseases (yes/no)	90/486
Treatment with anticoagulant drugs (yes/no)	146/430
Smoke (yes/no)	330/246
Vitreous injection of anti-VEGF drugs (razumab/abciximab)	312/239

two-sided *P*-value of less than 0.05 was considered statistically significant.

Results

Baseline information features

Among the cohort of 576 patients, 329 (58%) were male and 247 (42%) were female. The mean age at the time of surgery was 55.67 years, with a standard deviation of 11.01 years. The entire patient group exhibited a mean body mass index (BMI) of 25.2 with a standard deviation of 1.28. The mean systolic blood pressure was recorded at 159.2 ± 16.65 mmHg, while the mean diastolic blood pressure was 96.7 ± 7.33 mmHg. The preoperative glycated hemoglobin (HbA1c) level averaged 8.18 ± 1.18%, and for patients experiencing recurrent hemorrhage, the mean HbA1c was 10.01 ± 0.61%. The duration of diabetes among the patients was 13.99 ± 6.49 years. The cohort included 74 patients with cardiovascular disease, 90 patients with cerebrovascular disease, and 146 patients requiring oral anticoagulants due to systemic complications. Additionally, 330 patients in the study were identified as smokers. The ratio of ranibizumab to aflibercept among patients who had previously received anti-VEGF treatment was 312:239, as detailed in Table 1. For patients experiencing recurrent hemorrhage, initial management involves conservative treatment utilizing pharmacological agents and intravitreal administration of anti-VEGF medications. In cases where there is no significant resolution of the hemorrhage, a subsequent vitrectomy is performed to evacuate the hemorrhagic material and achieve hemostasis by addressing the source of hemorrhage intraoperatively.

Table 2 Intraoperative parameters

Parameters	
Operation time (min)	
Mean (SD)	106.7 (22.0)
Range	61.0–155.0
Combined cataract surgery (yes/no)	314/262
Stages of diabetes retinopathy (IV/V/VI)	150/287/139
Silicone oil filling	387
Gas filling	138
Fluid filling	46

Upon examining the intraoperative indicators, it was determined that the mean overall operation duration was 106.7 ± 22.03 min. Specifically, 314 patients underwent cataract surgery. In terms of diabetes staging, 150, 287, and 139 patients were classified as stages IV, V, and VI, respectively. Additionally, 387 patients received silicone oil filling, 138 underwent gas filling, and 46 had left with fluid (without gas or silicone oil tamponade) (Table 2).

Comparison of information between recurrent and non-recurrent hemorrhage groups of patients

To compare patients with recurrent and non-recurrent hemorrhage, we examined various indicators before and during surgery (Table 3). The analysis revealed statistically significant differences between the two patient groups in terms of endodiathermy ($P < 0.001$), anticoagulant use ($P < 0.001$), cerebrovascular diseases ($P < 0.001$), smoking status ($P = 0.004$), glycosylated hemoglobin levels ($P < 0.001$) and BMI ($P < 0.001$). Conversely, other indicators did not demonstrate statistical significance between the groups.

Visual acuity comparison between recurrent and non-recurren themorrhage groups of patients

To assess the effect of recurrent hemorrhage on visual recovery in patients, we conducted a comparative analysis of visual acuity at multiple time points: preoperatively, and at 3, 15, 45, and 90 days postoperatively (Fig. 2, Table Supplementary 1). The findings indicated that the visual acuity of patients in the non-recurrent hemorrhage group demonstrated a significant improvement 3 days post-surgery, with a gradual enhancement observed over time ($P < 0.001$). Conversely, patients in the recurrent

Table 3 Comparative analysis of various factors between Non recurrent hemorrhage and recurrent hemorrhage groups after vitrectomy

	No (*N* = 547)	Yes (*N* = 29)	*P* value
Eye			0.209
OD	274 (50.1%)	18 (62.1%)	
OS	273 (49.9%)	11 (37.9%)	
Sex			0.580
Female	236 (43.1%)	11 (37.9%)	
Male	311 (56.9%)	18 (62.1%)	
Transpupillary thermotherapy			< 0.001
No	31 (5.7%)	27 (93.1%)	
Yes	516 (94.3%)	2 (6.9%)	
Drug			0.004
Aflibercept	235 (43.0%)	4 (13.8%)	
Lucentis	290 (53.0%)	22 (75.9%)	
None	22 (4.0%)	3 (10.3%)	
Cardiovascular disease			< 0.001
No	483 (88.3%)	19 (65.5%)	
Yes	64 (11.7%)	10 (34.5%)	
Cerebrovascular disease			< 0.001
No	473 (86.5%)	13 (44.8%)	
Yes	74 (13.5%)	16 (55.2%)	
Cataract			0.282
No	246 (45.0%)	16 (55.2%)	
Yes	301 (55.0%)	13 (44.8%)	
Anticoagulants			< 0.001
No	425 (77.7%)	5 (17.2%)	
Yes	122 (22.3%)	24 (82.8%)	
Filling			< 0.001
Gas	27 (4.9%)	19 (65.5%)	
Silicon oil	390 (71.3%)	2 (6.9%)	
Water	130 (23.8%)	8 (27.6%)	
Smoking			0.004
No	241 (44.1%)	5 (17.2%)	
Yes	306 (55.9%)	24 (82.8%)	
Age (years)			0.024
Mean (SD)	55.428 (11.090)	60.172 (8.401)	
Range	15.000–84.000	40.000–72.000	
Diabetic duration (years)			0.070
Mean (SD)	14.106 (6.475)	11.862 (6.507)	
Range	1.000–25.000	4.000–25.000	
DR grade			0.027
4	141 (25.8%)	9 (31.0%)	
5	268 (49.0%)	19 (65.5%)	
6	138 (25.2%)	1 (3.4%)	
Glucose pre (mmol/L)			0.372
Mean (SD)	6.007 (1.167)	6.207 (1.214)	
Range	3.840–7.990	4.170–7.990	
Glycated hemoglobin (%)			< 0.001
Mean (SD)	8.078 (1.116)	10.102 (0.608)	
Range	6.000–10.930	7.750–10.850	
BMI (kg/m^2)			< 0.001
Mean (SD)	25.144 (1.258)	26.260 (1.313)	
Range	23.000–30.500	23.310–28.740	
Systolic blood pressure (mmHg)			0.020

Table 3 (continued)

	No (*N* = 547)	Yes (*N* = 29)	*P* value
Mean (SD)	158.821 (16.300)	166.207 (21.483)	
Range	130.000–199.000	127.000–198.000	
Diastolic blood pressure (mmHg)			0.897
Mean (SD)	96.698 (7.288)	96.517 (8.288)	
Range	70.000–110.000	85.000–110.000	
Surgical time (minutes)			0.044
Mean (SD)	107.088 (22.104)	98.655 (19.104)	
Range	61.000–155.000	65.000–140.000	
IOP pre (mmHg)			0.122
Mean (SD)	15.331 (3.537)	16.379 (3.793)	
Range	10.000–21.000	10.000–21.000	
IOP at 3 days (mmHg)			0.814
Mean (SD)	15.903 (4.005)	15.724 (3.442)	
Range	10.000–29.000	11.000–21.000	
IOP at 15 days (mmHg)			0.683
Mean (SD)	15.612 (3.432)	15.345 (3.498)	
Range	10.000–24.000	10.000–21.000	
IOP at 45 days (mmHg)			0.098
Mean (SD)	15.729 (3.594)	14.586 (4.128)	
Range	10.000–30.000	10.000–25.000	
IOP at 90 days (mmHg)			0.632
Mean (SD)	16.062 (4.626)	16.483 (4.085)	
Range	10.000–42.000	10.000–31.000	

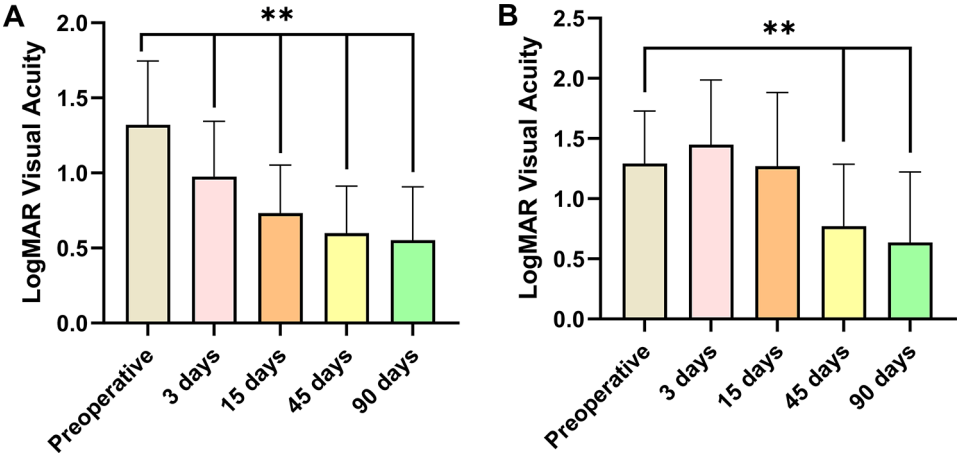

Fig. 2 Comparison of best-corrected visual acuity (BCVA) before and after surgery at 3, 15, 45, and 90 days. (**A**) Non-recurrent hemorrhage group. (**B**) Recurrent hemorrhage group. (**, $P < 0.01$)

hemorrhage group exhibited a decline in visual acuity at both 3 days and 15 days following surgery, relative to their preoperative status, with notable improvement occurring only after a period of 45 days ($P = 0.003$).

Analysis of risk factors for recurrent hemorrhage

To investigate the risk factors associated with recurrent hemorrhage in the future, we conducted a RF analysis. In the RF analysis, the number of decision trees was first evaluated. The variables were modeled five times, and the number of features corresponding to the minimum OOB error rate was determined as the optimal number of features. As shown in Figure S1, 500 decision trees yielded the lowest OOB error rate, and the optimal number of features was identified as six. ROC analysis of the top six variables (i.e., transpupillary thermotherapy, cerebrovascular disease, anticoagulants, filling, glycated hemoglobin, and BMI) showed that the AUC reached 0.87, indicating good model performance (Figure S2). In the univariate analysis, all six variables were significantly associated with recurrent hemorrhage ($P < 0.001$ for all). Among them, cerebrovascular disease (OR = 7.87),

anticoagulant use (OR = 16.72), and elevated glycated hemoglobin levels (OR = 21.22) exhibited particularly strong associations (Table 4). In the multivariate analysis, only anticoagulant use (OR = 120.77, $P = 0.020$) and glycated hemoglobin levels (OR = 18.41, $P = 0.001$) remained independently associated with recurrent hemorrhage (Table 4).

Discussion

DR is a common microvascular complication and a leading cause of visual impairment and blindness worldwide [19]. Epidemiologic studies of DR in the 1980s showed that 97% of young-onset insulin-treated diabetics developed retinopathy 20 years after diagnosis, and that the prevalence of DR was high in older-onset diabetics [20]. Since DR is one of the systemic complications of diabetes and symptoms usually appear late in the diabetic disease process, it is completely vital to understand DRs as they can prevent vision loss and are cost-effective [21]. Clinically, DR can be categorized into two stages: NPDR and PDR [22]. Since the 1970s, plain vitrectomy has become the standard treatment for PDR-associated nonrevolving VH [23]. Today, vitrectomy plays a definite role in the treatment of detached retinas with traction associated with severe fibrovascular proliferation in PDR [1]. In addition, vitreous cavity injection of anti-VEGF drugs is currently the main treatment for early and advanced DR. Conventional laser treatment can only stabilize vision, while anti-VEGF drug treatment can improve vision with fewer ocular adverse effects [24].

In the current study, we identified significant differences between the two groups in terms of transpupillary thermotherapy, anticoagulant medication usage, presence of cardiovascular and cerebrovascular diseases, intraocular filler application, smoking, age, DR staging, HbA1c, BMI, systolic blood pressure, and surgical time. Cerebrovascular disease, oral anticoagulants, HbA1c and BMI are factors that may contribute to an increased risk of postoperative recurrent hemorrhage. Conversely, the application of endodiathermy, silicone oil and liquid intraocular tamponade may mitigate the risk of postoperative recurrent hemorrhage. Given that the patients' fundopathy was an ocular complication resulting from diabetes, our study concentrated on comparing their fasting blood glucose levels and HbA1c values. In the current study, patients' fasting blood glucose levels were observed to be within the normal range and did not influence the occurrence of recurrent hemorrhage. However, elevated HbA1c levels were noted in patients experiencing recurrent hemorrhage, suggesting a potential association with an increased incidence of this condition. Previous research has demonstrated that a 1% decrease in HbA1c is correlated with a 37% reduction in the risk of microvascular complications, particularly DR [25]. Furthermore, the overall accuracy of HbA1c in diagnosing DR is commendable. Given its greater stability compared to blood glucose levels and its insensitivity to dietary fluctuations, HbA1c may serve as an appropriate indicator for DR [26]. Regarding anticoagulant usage, our findings indicate a variation in the administration of anticoagulants between the two patient groups, suggesting that their use may contribute to an elevated risk of recurrent postoperative hemorrhage. In contrast, previous studies have shown that the use of oral anticoagulants does not increase the risk of fundus hemorrhage in DR patients [27]. Nevertheless, the participants in our study were patients experiencing recurrent hemorrhage, and a reduction in coagulation function could lead to recurrent hemorrhage in the early postoperative period as a consequence of the anticoagulant drug's effects. Regarding

Table 4 Univariate and multivariate logistic regression analyses of risk factors for recurrent hemorrhage in diabetic retinopathy patients after vitrectomy

		Non-recurrent hemorrhage ($N = 547$)	Recurrent hemorrhage ($N = 29$)	Univariable OR (95% CI, P value)	Multivariable OR (95% CI, P value)
Transpupillary thermotherapy	No	31 (5.7%)	27 (93.1%)		
	Yes	516 (94.3%)	2 (6.9%)	0.00 (0.00-0.02, $P < 0.001$)	0.00 (0.00-0.08, $P < 0.001$)
Cerebrovascular disease	No	473 (86.5%)	13 (44.8%)		
	Yes	74 (13.5%)	16 (55.2%)	7.87 (3.64–17.02, $P < 0.001$)	0.22 (0.01–4.75, $P = 0.334$)
Anticoagulants	No	425 (77.7%)	5 (17.2%)		
	Yes	122 (22.3%)	24 (82.8%)	16.72 (6.25–44.75, $P < 0.001$)	120.77 (2.14-6825.30, $P = 0.020$)
Filling	Gas	27 (4.9%)	19 (65.5%)		
	Silicon oil	390 (71.3%)	2 (6.9%)	0.01 (0.00-0.03, $P < 0.001$)	0.11 (0.01–1.80, $P = 0.121$)
	Water	130 (23.8%)	8 (27.6%)	0.09 (0.03–0.22, $P < 0.001$)	1.03 (0.08–12.99, $P = 0.985$)
Glycated hemoglobin	Mean ± SD	8.1 ± 1.1	10.1 ± 0.6	21.22 (8.31–54.19, $P < 0.001$)	18.41 (3.14-107.94, $P = 0.001$)
BMI	Mean ± SD	25.1 ± 1.3	26.3 ± 1.3	2.10 (1.49–2.96, $P < 0.001$)	1.74 (0.60–5.01, $P = 0.305$)

OR, odds ratio; CI, confidence interval

intraocular injections, prior research has demonstrated comparable therapeutic efficacy between ranibizumab and aflibercept, with the latter requiring fewer injection needles [28]. A research demonstrated that the aflibercept is more effective in inhibiting neovascularization in age-related macular degeneration [29]. No statistically significant difference was observed in this study, potentially attributable to the limited sample size of patients experiencing recurrent hemorrhage. Furthermore, the study demonstrates that endodiathermy effectively reduces the incidence of recurrent hemorrhage, possibly due to its ability to achieve a more secure closure of the hemorrhage site compared to laser closure [30]. Cardiovascular and cerebrovascular diseases significantly influence postoperative vascular stability. Chronic hypertension contributes to retinal arteriosclerosis and reduces the elasticity of vascular walls [31]. Postoperative inflammation or alterations in posture, such as adopting a prone position, can result in blood pressure fluctuations [32]. These fluctuations may precipitate microvascular rupture or leakage, thereby elevating the risk of postoperative hemorrhage. Additionally, there is a reduction in the synthesis of nitric oxide (NO) and an increase in the release of vasoconstrictors, such as endothelin-1, which can lead to postoperative vascular spasm and exacerbate ischemia-reperfusion injury [33]. Furthermore, patients with cardiovascular and cerebrovascular diseases frequently exhibit heightened platelet activity and elevated fibrinogen levels, which can facilitate the formation of microthrombi post-surgery, obstruct retinal capillaries, and induce neovascularization [34]. Based on our observations, we posit that patients with a prolonged duration of diabetes may exhibit more advanced stages of DR. Consequently, the complexity and duration of surgical procedures may increase. Furthermore, the severity of the disease may necessitate a greater reliance on silicone oil, which, due to its topical pressure effect, could be beneficial in mitigating postoperative hemorrhage. Previous studies have shown that silicone oil tamponade may limit recurrent hemorrhage after surgery [35]. It is thought that mechanical hemostasis may work by the following means: after the silicone oil is filled in the vitreous cavity, its surface tension can exert a compressive effect on the hemorrhage site, thereby reducing the occurrence of postoperative hemorrhage. Blocking inflammatory factors: Silicone oil has a mechanical blocking effect on inflammatory factors and inflammatory cells, which can limit the dissemination of inflammation in the eye, thereby indirectly reducing the risk of bleeding. Provide a stable environment: Silicone oil tamponade buys time for retinal photocoagulation and helps reduce the possibility of recurrent hemorrhage after surgery.

There are two peaks of vitreous hemorrhage after vitrectomy in diabetic patients. The first peak is often seen at the end of the first week, which is due to residual blood dispersion or hemorrhage from the vascular stump. The second peak occurs between the second and third month, which may be due to fibrovascular growth at the incision site or recurrent hemorrhage after neovascularization of the patient's retinal ischemia [36]. Significant efforts have been made to reduce the risk of VH after vitrectomy, such as intraoperative prophylactic freezing to inhibit fibrovascular growth at the scleral dissection site, intravitreal long-acting gas tamponade to stop hemorrhage, intraoperative elevation of intraocular pressure and tretinoin injections [37–39]. After surgery, intravitreal anti-VEGF or oral hemostatic and circulation-improving drugs are given to prevent the hemorrhage [40]. Several methods have been used to prevent postoperative recurrent hemorrhage in patients with DR, but postoperative recurrent hemorrhage cannot be completely avoided and can lead to phthisis bulbi if the hemorrhage is not treated aggressively. And the sources of recurrent hemorrhage after vitrectomy may include neovascularization growing at the scleral dissection, residual or recurrent optic nerve fibrovascular membrane, inadequate retinal photocoagulation, residual or recurrent neovascularization on the retina, retinal ischemia and postoperative low intraocular pressure. In clinical practice, the findings of this study indicate its utility in identifying high-risk patient populations. Specifically, patients with a prolonged history of diabetes exceeding ten years, an HbA1c level greater than 7.5%, and concurrent systemic diseases should be categorized as high-risk groups. It is imperative to enhance glycemic control prior to surgical interventions, aiming to reduce the patient's HbA1c to below 7% and maintain fasting blood glucose levels within the range of 6–8 mmol/L. Furthermore, early postoperative dynamic monitoring and prompt management of recurrent hemorrhage are recommended. Future research should investigate the impact of continuous glucose monitoring and personalized glucose control programs on hemorrhage risk, with a particular focus on their preventive effects on early postoperative hemorrhage peaks. Additionally, the efficacy of combining intraoperative prophylactic cryotherapy with long-acting anti-VEGF drug delivery systems warrants further examination, particularly in addressing the secondary hemorrhage peak associated with fibrous vascular hyperplasia at the scleral incision site.

This study has certain limitations, particularly concerning the sample size inherent in retrospective analyses of the relatively uncommon complication of recurrent hemorrhage. Despite these constraints, the study offers a valuable foundation for risk factor analysis and prognosis evaluation through comprehensive examination of risk factors. The sample size of the recurrent hemorrhage

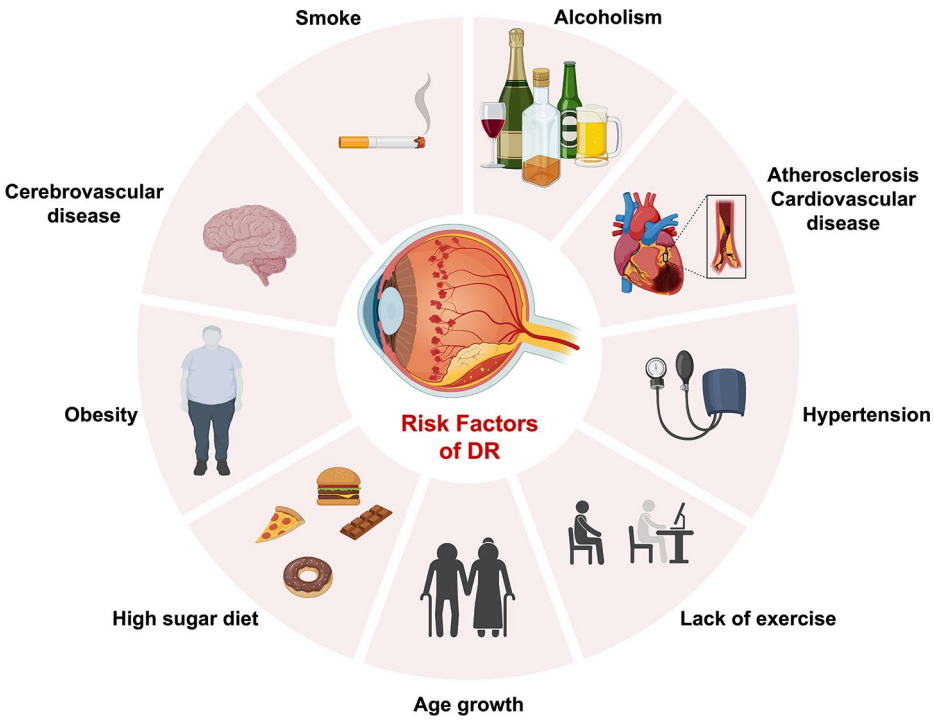

Fig. 3 Risk factors associated with diabetic retinopathy

group ($N = 29$) is relatively limited, which accurately represents the actual prevalence of the condition.

Conclusion

In conclusion, individuals with VH secondary to DR exhibit an increased likelihood of recurrent hemorrhage following surgical intervention. Our findings suggest that predominantly attributed to prolonged hyperglycemia, tobacco use, elevated body mass index, and the presence of systemic complications, as illustrated in Fig. 3. In summary, this indicates that the physiological parameters are inadequately regulated. Consequently, it is essential to implement dietary management, address systemic complications, enhance moderate physical activity, and conduct regular evaluations of early interventions. These measures are crucial to stabilizing and improving the physical condition of diabetic patients and minimizing the incidence of recurrent hemorrhagic events. Our research increased awareness of these risk factors in postoperative management and patient counseling, would be valuable.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12886-025-04112-w.

Supplementary Material 1: Determination of the optimal number of decision trees (A) and variables (B) in random forest analysis.

Supplementary Material 2: Variables included in the model based on the optimal number of variables (A); Receiver operating characteristic curve of the combined six variables (B).

Supplementary Material 3: Comparison of best-corrected visual acuity (BCVA) between non-recurrent and recurrent hemorrhage groups.

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Author contributions

SL made substantial contributions to the conception of the work, design of the work, acquisition of data, verification of data, analysis of data, interpretation of data, and drafted the worked. HL conducted statistical analyses and replicability analyses. CM assisted in the interpretation of data and assisted in drafting the work. XL contributed to verification of data, analysis of data, interpretation of data, and drafted the worked. All authors revised the work, approved the submitted version, and agreed to be personally accountable for their contributions.

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Data availability

Data are available from the corresponding author upon reasonable request, subject to privacy/ethical restrictions.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Review Committee of Zhengzhou University (2022-KY-0343-004) and conducted in accordance with the principles of the Declaration of Helsinki. All participants provided written informed consent.

Consent for publication

Not applicable. All data presented in this study are anonymized.

Competing interests
The authors declare no competing interests.

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