

Risk of Hemorrhagic Complications and Secondary Surgery in Patients on Warfarin vs DOACs Undergoing Glaucoma Surgery

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Purpose: To compare the risk of postoperative ocular hemorrhagic complications and reoperation in glaucoma surgery patients taking warfarin versus direct oral anticoagulants (DOACs).

Patients and Methods: This retrospective cohort study used the TriNetX global federated health research network. We identified 15,336 glaucoma surgery patients on warfarin and 22,358 on DOACs between January 1, 2000 and January 1, 2025. After 1:1 propensity score matching for age, gender, race, Type 2 Diabetes, hypertension, hyperlipidemia, and nicotine dependence, 15,019 patients remained in each cohort. We analyzed postoperative hemorrhagic complications within 1 year, including vitreous, conjunctival, retinal, and choroidal hemorrhages; hyphema; mitomycin injection; and periocular hemorrhage. Risk ratios (RRs) and 95% confidence intervals (CIs) were calculated, with significance set at $p < 0.05$. A secondary analysis assessed reoperation risk among those who experienced hemorrhagic complications. Patients on anticoagulants were compared to glaucoma patients with hemorrhagic complications who were not on anticoagulants. Reoperations included repeat trabeculectomy and aqueous shunt revision/insertion.

Results: Warfarin was associated with significantly higher risk of vitreous hemorrhage (RR 1.949, CI 1.563–2.321, $p < 0.0001$), conjunctival hemorrhage (RR 1.329, CI 1.007–1.710, $p = 0.0459$), retinal hemorrhage (RR 1.512, CI 1.145–1.997, $p = 0.0033$), and hyphema (RR 1.740, CI 1.240–2.462, $p = 0.0015$). No increased risk was found for choroidal hemorrhage or postoperative mitomycin C injection. Hemorrhagic complications did not increase reoperation risk in patients on anticoagulants compared to controls.

Conclusion: Warfarin use is linked to higher ocular hemorrhagic complication rates post-glaucoma surgery compared to DOACs. Anticoagulants use did not increase the risk of reoperation.

Keywords: trabeculectomy, outcomes, propensity matching, pharmacotherapy

Introduction

Warfarin is a common prophylactic anticoagulant medication used in conditions such as atrial fibrillation that aims to prevent thromboembolic events. It has long been a cornerstone therapy among anticoagulants in reducing the risk of stroke and other life-threatening ischemic events; however, its use requires caution due to its narrow therapeutic index and significant bleeding risk.

In 2010, a new class of anticoagulant medications, the direct oral anticoagulants (DOACs), was approved for clinical use by the FDA. In recent years, these have become preferred over warfarin due to their efficacy, fewer adverse effects, and reduced need for routine monitoring.¹ In 2011, 52.4% of patients with atrial fibrillation were on warfarin compared to only 4.7 with DOACs. By 2020, warfarin use had declined to 17.7% while DOAC usage has risen to 47.9%.² However, DOACs still risk bleeding events like warfarin.³

Although warfarin and direct oral-acting anticoagulants carry bleeding risk, their mechanisms of action differ, and these differences may have clinical relevance in a surgical setting. Warfarin is a Vitamin K antagonist that reduces synthesis of hepatic clotting factors.⁴ In contrast, DOACs achieve anticoagulation through direct inhibition of either thrombin or factor Xa.⁵

Most comparisons of warfarin to DOACs assess risk of stroke and other systemic embolic events in patients with cardiovascular pathologies. To our knowledge, however, no studies have compared adverse hemorrhagic outcomes in patients who underwent glaucoma filtration surgery while taking one of these two types of anticoagulants. For the purposes of this study, filtration surgery in this study specifically refers to trabeculectomy and aqueous shunt revision or repair.

Glaucoma filtering surgery carries a small but potential risk of severe, sight-threatening hemorrhagic complications. Suprachoroidal hemorrhage, for example, occurs in approximately 0.8 ($\pm 0.05\%$) of trabeculectomy or tube shunt procedures, resulting in vision loss.⁶ Other hemorrhagic complications include hyphema, vitreous hemorrhage, and retinal hemorrhage, which can also compromise postoperative vision.⁷ Known risk factors include advanced age, myopia, aphakia, and prior intraocular surgery.⁸ Because systemic anticoagulation increases baseline bleeding risk, the type of anticoagulant prescribed may influence surgical safety and outcomes. Understanding these risks of is critical for ophthalmologists and other providers involved in perioperative care.

This study compares the risk of developing hemorrhagic ocular complications in patients taking warfarin who underwent trabeculectomy or aqueous shunt procedures versus those taking direct oral-acting anticoagulants (DOACs). This study also evaluates whether patients in either group who developed such complications were at higher risk for needing secondary revision or reoperation following their initial surgery.

Materials and Methods

We conducted a retrospective study using the TriNetX global federated health research network, which contains data from 114,458,327 patients across 67 health care organizations (HCOs). Because this study utilizes deidentified electronic health data, it was exempted for institutional review board (IRB) approval. TriNetX is in compliance with the Health Insurance Portability and Accountability Act and utilizes medical codes gathered from the *International Classification of Diseases, 10th edition (ICD-10)* and Current Procedural Terminology (CPT) codes. This retrospective study is exempt from informed consent. The data reviewed is a secondary analysis of existing data, does not involve intervention or interaction with human subjects, and is de-identified per the de-identification standard defined in Section §164.514(a) of the HIPAA Privacy Rule. The process by which the data is de-identified is attested to through a formal determination by a qualified expert as defined in Section §164.514(b)(1) of the HIPAA Privacy Rule. This formal determination by a qualified expert refreshed on December 2020. Data was collected for this study on February 16th, 2025, and includes diagnoses, procedures, medications, and lab values. Subsequent statistical analyses were performed within the TriNetX software.

Patients aged 18 years or older were filtered and included based on having undergone filtering glaucoma surgery, which included trabeculectomy (CPT: 66,170, 66,172, 65,850), and aqueous shunt (CPT: 66,174, 66,175, 66,179, 66,180). Only instances of patients' first glaucoma surgery were included in the study to exclude bias from having undergone multiple operations. These first-time glaucoma surgery patients were then stratified into 2 unique cohorts based on anticoagulant use. The first group includes patients that took warfarin prior to surgery. The second group included patients taking a DOAC, including rivaroxaban (Xarelto), betrixaban (Bevyxxa), dabigatran etexilate (Pradaxa), edoxaban (Savaysa), or apixaban (Eliquis) prior to glaucoma surgery. The index event is defined as the day the patient underwent their first glaucoma surgery, and patients were studied for relevant outcomes up to 1 year after the index event.

Patients in the warfarin cohort were excluded from the study if they had ever taken DOACs previously, just as patients in the DOAC cohort were excluded if they had previously taken warfarin. Patients in both groups were also excluded if they had any history of the studied outcomes prior to the index date, including choroidal hemorrhage and rupture (ICD-10: H31.3), hyphema (ICD-10: H21.0), vitreous hemorrhage (ICD-10: H43.1), conjunctival hemorrhage (ICD-10: H11.3), mitomycin injection, retinal hemorrhage (ICD-10: H35.6), or contusion of the periocular area (ICD-10: S00.1).

Prior to analysis, each cohort was propensity matched for pertinent factors that may increase postoperative bleeding risk. These variables include age, race, and gender as well as diagnoses of primary hypertension, hyperlipidemia, and nicotine dependence. We also specifically matched patients for diagnoses of diabetes mellitus, which is an established risk factor for retinal hemorrhage.⁹ These demographic factors and comorbidities were carefully included to match for underlying disparities that are risk factors for the outcomes we intend to study. Following propensity matching, an outcomes

analysis was conducted and was analyzed by calculating risk ratios (RRs) and 95% confidence intervals (95% CIs), with statistical significance set at $p < 0.05$.

After this outcomes analysis, a secondary study was conducted to determine the risk of needing a second glaucoma operation due to any studied complications in the first surgery. In this analysis, we first created a cohort of patients who underwent glaucoma surgery and had a hemorrhagic complication. Then, we filtered this group further to only include patients who were taking either warfarin or a DOAC. The second cohort, which served as the control, also included glaucoma surgery patients who had a studied hemorrhagic complication, but no patients in this cohort had ever taken warfarin or a DOAC. Only patients who experienced an adverse hemorrhagic ocular event for the first time were included in this study to exclude bias for patients who might be at higher risk for bleeding due to other factors. Propensity matching was conducted using the same covariates as the primary study, and these two cohorts were studied using an outcomes analysis that examined if there was an increased risk of having a second glaucoma operation up to 1 year after their first complication. “Second glaucoma operations” considered were repeat trabeculectomy, trabeculectomy revision, or any aqueous shunt revision/repair or re-insertion. Again, the outcomes analysis was conducted using RRs and 95% CIs, with statistical significance set at $p < 0.05$.

Results

15,336 patients on warfarin who underwent glaucoma surgery were identified, and 22,358 patients on DOACs were identified. After balancing for the covariates via 1:1 propensity score matching, 15,019 patients remained in each cohort for outcomes analysis, with standardized differences for each covariate <0.1 , as shown in Table 1 (see attached).

Table 1 Baseline Demographics of Warfarin vs DOAC Glaucoma Surgery Patients Before and After Propensity Score Matching

	Cohort	Before Matching (N = 18,448 / 24,766)	%	P-value (Before)	Std Diff. (Before)	After Matching (N = 18,041 / 18,041)	%	P-value (After)	Std Diff. (After)
Age at Index (Mean $\pm$ SD)	1	68.9 $\pm$ 15.2	100%	<0.001	0.111	69.1 $\pm$ 15.0	100%	0.749	0.003
	2	70.5 $\pm$ 14.4	100%			69.1 $\pm$ 15.1	100%		
Female	1	8274	45.60%	0.006	0.027	8245	45.70%	0.849	0.002
	2	11,622	46.90%			8263	45.80%		
Male	1	9844	54.20%	<0.001	0.036	9767	54.10%	0.849	0.002
	2	12,993	52.50%			9749	54.00%		
White	1	11,317	62.40%	<0.001	0.061	11,310	62.70%	0.243	0.012
	2	16,171	65.30%			11,417	63.30%		
Black or African American	1	2078	11.50%	0.632	0.005	2072	11.50%	0.518	0.007
	2	2873	11.60%			2033	11.30%		
Asian	1	516	2.80%	<0.001	0.04	516	2.90%	0.545	0.006
	2	878	3.50%			497	2.80%		
Hispanic or Latino	1	1114	6.10%	0.264	0.011	1110	6.20%	0.44	0.008
	2	1586	6.40%			1075	6.00%		
Not Hispanic or Latino	1	15,969	88.00%	<0.001	0.037	15,868	88.00%	0.241	0.012
	2	21,489	86.80%			15,940	88.40%		
American Indian/Alaska Native	1	42	0.20%	0.909	0.001	42	0.20%	0.123	0.016
	2	56	0.20%			29	0.20%		

(Continued)

Table 1 (Continued).

	Cohort	Before Matching (N = 18,448 / 24,766)	%	P-value (Before)	Std Diff. (Before)	After Matching (N = 18,041 / 18,041)	%	P-value (After)	Std Diff. (After)
Native Hawaiian/Pacific Islander	1	16	0.10%	0.114	0.016	15	0.10%	0.564	0.006
	2	35	0.10%			12	0.10%		
Essential Hypertension	1	12,197	67.20%	<0.001	0.059	12,147	67.30%	0.831	0.002
	2	17,322	69.90%			12,128	67.20%		
Hyperlipidemia	1	8651	47.70%	<0.001	0.146	8648	47.90%	0.833	0.002
	2	13,613	55.00%			8668	48.00%		
Diabetes Mellitus	1	5738	31.60%	0.267	0.011	5710	31.70%	0.084	0.018
	2	7956	32.10%			5558	30.80%		
Nicotine Dependence	1	1528	8.40%	<0.001	0.058	1528	8.50%	0.163	0.015
	2	2498	10.10%			1455	8.10%		

Patients taking warfarin showed significantly higher risk of various hemorrhagic postoperative complications following glaucoma surgery compared to those on DOACs. Specifically, there was an increased risk of developing vitreous hemorrhage (RR 1.949, 95% CI 1.563–2.431, $p < 0.0001$), conjunctival hemorrhage (RR 1.329, 95% CI 1.007–1.710, $p = 0.0459$), retinal hemorrhage (RR 1.512, 95% CI 1.145–1.997, $p = 0.0033$), and hyphema (RR 1.74, 95% CI 1.24–2.462, $p = 0.0015$). Other outcomes showed no significance, including choroidal hemorrhage (RR 1.556, 95% CI 0.861–2.811, $p = 0.1401$), mitomycin injection (either intraoperative or postoperative) (RR = 1.167, 95% CI 0.66–2.189, $p = 0.6307$), and periocular hemorrhage (RR = 0.783, 95% CI 0.422–1.45, $p = 0.4346$), as shown in Table 2. Residual confounding due to unmeasured variables, such as glaucoma severity, corneal thickness, and surgeon experience, cannot be excluded and may have influenced the observed outcomes.

In the secondary analysis, we identified 623 patients on either warfarin or DOACs who, undergoing initial glaucoma surgery, experienced an adverse outcome as well as 12,871 in the control group. After 1:1 propensity score matching with the same covariates in the first study, 616 patients remained in each cohort with standardized differences for each covariate <0.1 , as shown in Table 3.

Patients on warfarin did exhibit increased risk for some hemorrhagic complications following glaucoma surgery compared to patients on DOACs. However, when we analyzed patients on either anticoagulant who did develop

Table 2 Postoperative Risk Outcomes Comparison Between Glaucoma Patients on Warfarin vs DOACs

Outcome	Glaucoma Surgery Patients on Warfarin (% Risk)	Glaucoma Surgery Patients on DOACs (% risk)	Risk Ratio	95% CI	P-value
Vitreous Hemorrhage	230 (1.531%)	118 (0.786%)	1.949	(1.563, 2.431)	<0.0001
Conjunctival Hemorrhage	113 (0.752%)	85 (0.566%)	1.329	(1.007, 1.710)	0.0459
Retinal hemorrhage	124 (0.826%)	82 (0.546%)	1.512	(1.145, 1.997)	0.0033
Hyphema	87 (0.579%)	50 (0.333%)	1.74	(1.24, 2.462)	0.0015
Choroidal Hemorrhage and rupture	28 (0.186%)	18 (0.12%)	1.556	(0.861, 2.811)	0.1401
Mitomycin injection	21 (0.14%)	18 (0.12%)	1.167	(0.66, 2.189)	0.6307
Periocular hemorrhage	18 (0.12%)	23 (0.153%)	0.783	(0.422, 1.45)	0.4346

Table 3 Baseline Demographics of Glaucoma Surgery Patients on Either Anticoagulant Before and After Propensity Score Matching

Characteristic	Cohort	Before Matching (N = 623 / 12,871)	% of Cohort	P-value (Before)	Std Diff. (Before)	After Matching (N = 616 / 616)	% of Cohort	P-value (After)	Std Diff. (After)
Age at Index (Mean $\pm$ SD)	1	67.2 $\pm$ 15.3	100%	<0.001	0.544	67.2 $\pm$ 15.3	100%	0.238	0.067
	2	57.9 $\pm$ 18.5	100%			68.1 $\pm$ 13.8	100%		
Female	1	263	42.60%	0.396	0.035	263	42.70%	0.774	0.016
	2	5135	44.40%			268	43.50%		
Male	1	353	57.20%	0.073	0.074	352	57.10%	0.73	0.02
	2	6195	53.50%			346	56.20%		
White	1	372	60.30%	0.102	0.068	371	60.20%	0.483	0.04
	2	6591	56.90%			383	62.20%		
Black or African American	1	116	18.80%	0.004	0.113	116	18.80%	1	<0.001
	2	1689	14.60%			116	18.80%		
Asian	1	15	2.40%	0.14	0.066	15	2.40%	0.312	0.058
	2	411	3.60%			10	1.60%		
American Indian or Alaska Native	1	10	1.60%	0.002	0.099	10	1.60%	1	<0.001
	2	68	0.60%			10	1.60%		
Hispanic or Latino	1	71	11.50%	<0.001	0.189	71	11.50%	0.787	0.015
	2	2105	18.20%		68	68	11.00%		
Not Hispanic or Latino	1	478	77.50%	<0.001	0.264	477	77.40%	0.891	0.008
	2	7598	65.60%			479	77.80%		
Hyperlipidemia	1	332	53.80%	<0.001	0.061	331	53.70%	0.864	0.024
	2	3261	28.20%			328	53.20%		
Diabetes Mellitus	1	357	57.90%	<0.001	0.072	357	58.00%	0.908	0.032
	2	5369	46.40%			355	57.60%		
Nicotine Dependence	1	93	15.10%	<0.001	0.058	92	14.90%	0.052	0.02
	2	900	7.80%			69	11.20%		
Essential Hypertension	1	479	77.60%	<0.001	0.265	478	77.60%	0.684	0.022
	2	5466	47.20%			472	76.60%		

Table 4 Glaucoma Secondary Operation Risk Comparison Between Patients on Anticoagulants vs Control

Outcome	Glaucoma Surgery Patients on Warfarin (% Risk)	Glaucoma Surgery Patients on DOACs (% risk)	Risk Ratio	95% CI	P-value
Revision Trabeculectomy	34 (0.039%)	17 (0.028%)	1.412	(0.766, 2.601)	0.266
Aqueous shunt revision / insertion	49 (0.080%)	53 (0.086%)	0.925	(0.637, 1.341)	0.679

a complication and compared them to the control, we found no increased risk of needing secondary glaucoma surgical interventions. Specifically, there was no statistically significant increased risk for undergoing a repeat trabeculectomy (RR = 1.412, 95% CI 0.766–2.601, $p = 0.2662$) or an aqueous shunt revision/repair (RR = 0.925, 95% CI 0.637–1.341, $p = 0.6792$) whether on warfarin or a DOAC. These results are illustrated in Table 4. Residual confounding due to unmeasured variables, such as adherence to postoperative medications and ocular comorbidities cannot be excluded and may have influenced the observed outcomes.

These findings suggest patients on warfarin may have increased risk of developing certain hemorrhagic complications after glaucoma surgery compared to those patients on DOACs, but these complications do not necessarily increase the risk of requiring a secondary glaucoma surgery.

Discussion

We observe from the results of this retrospective cohort study that glaucoma surgery patients on warfarin had increased risk of developing vitreous hemorrhage, conjunctival hemorrhage, retinal hemorrhage, and hyphema compared to a matched group of patients on DOACs after 1 year, but they did not have increased risk of developing choroidal hemorrhage, periocular hemorrhage, or need of mitomycin injection during or following glaucoma surgery. These findings are impactful because these adverse outcomes have varying prognoses. For example, suprachoroidal hemorrhage is a feared complication, as most patients do not recover a visual acuity of 20/200 or better.¹⁰ Most cases of hyphema resolve without visual deficits, although patients with higher grade hyphema may have a worse prognosis.¹¹ Retinal vitreous hemorrhages vary in prognosis, but they tend to resolve spontaneously if occurring after glaucoma surgery.¹² Outcomes including vitreous hemorrhage,¹³ conjunctival hemorrhage, and periocular hemorrhage generally exhibited spontaneous clearance (specifically after glaucoma surgery) with no associated visual loss, with conjunctival hemorrhage resolving in 1–2 weeks.¹⁴ When correlating these prognoses with our findings, it appears that although patients on warfarin had higher risks of certain types of bleeding, these bleeding occurrences were more likely to resolve spontaneously with very low risk of permanent adverse visual outcomes. Additionally, severe vision-threatening hemorrhagic complications (like suprachoroidal hemorrhage) showed no difference in risk between patients on warfarin vs DOACs.

The observed increased risk of certain hemorrhagic complications in patients on warfarin compared to DOACs is possibly due to both mechanistic and pharmacokinetic etiologies. Whereas warfarin targets several different vitamin K-dependent clotting factors (II, VII, IX, and X) as well as proteins C and S, DOACs target a single factor (either thrombin or factor Xa). This more targeted mechanism leads to a predictable anticoagulant effect with fewer dietary, comorbidity, or genetic interactions.¹ Additionally, adverse anticoagulant effects are known to occur due to dosing errors and monitoring difficulties. Because of warfarin's narrow therapeutic index and required routine lab monitoring, patients are likely to be outside the therapeutic range and thus at higher risk of adverse bleeding.¹⁵

The results of this study indicate that anticoagulant use may not be associated with increased risk of needing a secondary glaucoma operation. In other words, anticoagulant use may not necessarily be a risk factor for complications requiring secondary glaucoma surgery revision/repair. Other studies have established certain modifiable and non-modifiable risk factors for secondary glaucoma surgical intervention. Shanmugam et al found that females, patients younger than 65, and African-American race were all associated with an increased risk of failed primary glaucoma surgery and need for secondary glaucoma surgery.¹⁶ Smoking was also noted to be a strong risk factor, suggesting that

smoking-induced cytokines and free radical damage may play a pivotal role in failed glaucoma surgery.¹⁷ This corroborates our study's decision to include nicotine dependence as a covariate when propensity matching both cohorts.

One area of active clinical discussion is the discontinuation of anticoagulant medications prior to glaucoma surgery due to risk of bleeding. Currently, the literature has not reached a consensus on the single best practice for patients requiring glaucoma filtration surgery. One leading argument, however, is that although maintenance of warfarin and DOACs increase the risk of certain hemorrhagic events following glaucoma surgery, these dangers are outweighed by the risk of systemic thromboembolic events, such as myocardial infarction or stroke if patients discontinue anticoagulant use before surgery.¹⁸ Although not definitive, our study provides additional perspective to this ongoing discussion. Our results indicate potentially increased risk of specific types of ocular bleeding in warfarin vs DOAC patients, but these outcomes do not necessarily correlate with impaired visual acuity or permanent adverse outcomes. Our results also could not establish anticoagulant use as a risk factor for needing secondary glaucoma surgery. Based on these findings, there may be clinical evidence to keep patients on anticoagulant medication prior to glaucoma filtration surgery despite the aforementioned potential associated risks. However, further studies comparing risks of hemorrhagic complications with continuation of anticoagulant medications to risks of thromboembolic events with cessation of these drugs are needed to confidently answer this clinically relevant question. It is worth noting that researchers have reached a broader consensus for continuing anticoagulant use in cataract surgery despite its risks because anticoagulants were not associated with increased bleeding events in cataract surgery.¹⁹

Because of their safety and efficacy, clinicians may prefer DOACs over warfarin. Several studies also corroborate this preference, as seen in one study conducted by Fang et al, which studied rates of recurrent venous thromboemboli in patients with venous thromboembolism (VTE). This study found that the cohort of patients taking DOACs was associated with a lower risk of recurrent VTE compared to those patients on warfarin.²⁰ Another systematic review/meta-analysis conducted by Zeng et al found that, in atrial fibrillation patients, DOAC therapy reduced the risk of ischemic stroke, hemorrhagic stroke, intracranial hemorrhage, and all-cause death but did not find a change in difference in risk for gastrointestinal bleeding.¹ However, like these studies, most research directly comparing warfarin to DOAC assesses cardiovascular pathologies and studies outcomes like stroke that affect the systemic vasculature. The only similar study in the literature pertaining to ophthalmic outcomes studied conversion rates to neovascular disease in patients with non-neovascular age-related macular degeneration with warfarin vs DOAC use.²¹

Although warfarin has not been directly compared to DOACs to assess hemorrhagic risks after glaucoma surgery, studies that assessed anticoagulant and antiplatelet use in glaucoma surgery do exist. Law et al specifically compared anticoagulant with antiplatelet therapy in terms of risk of hemorrhagic complications after glaucoma surgery.²² This study found that both antiplatelet therapies and anticoagulants were associated with increased hemorrhagic risk, but they also determined that patients on anticoagulant therapy preoperatively also had a higher risk of hemorrhagic complications compared to those on antiplatelet therapy. Another finding was that patients on anticoagulant therapy who did not cease therapy prior had the highest risk of developing an adverse bleeding outcome. As Law's paper looked at anticoagulants as a single pharmacological class and confirmed their use to be the highest-risk for bleeding outcomes, our paper stratified anticoagulants based on their unique mechanisms of action and found different rates of hemorrhagic risk within the classes of anticoagulants themselves.

One strength of this retrospective cohort study is the use of a global database, allowing for robust patient populations in each cohort. Thus, the results of this study may allow for greater generalizability when assessing the clinical utility of these findings. The strength of this study is also exemplified through rigorous propensity matching for confounding variables that include accounting for age, sex, race, and relevant diagnoses. This improves the quality of the data set and allows our study to partially eliminate a significant source of potential bias.

This study also carries some limitations that may influence the accuracy of the results. One potential weakness is the use of ICD-10 and CPT codes. Although these attempt to serve as a standardization of medical procedures, diagnoses, and medications, physicians may utilize codes differently, fail to include all relevant codes pertaining to the patient, or may include too many codes. This along with the fact that our study may not have included every unique code related to glaucoma surgery may result in inaccuracies when trying to capture all the glaucoma surgery patients in the database who were either taking warfarin or DOACs, for example. One limitation can also be seen with our inability to study

exclusively postoperative mitomycin C injections as an outcome, as the relevant CPT code included both intraoperative and postoperative injections. Another limitation is that we could not include every possible covariate that may confound the results. Because the data was acquired from electronic health records, risk factors such as socioeconomic status or insurance status were not obtained. Because increasing the number of covariates for the statistical analysis decreases the weight of each factor, we selected to include only the most pertinent variables which may impact the validity of our results. Lastly, patients who had concurrent surgeries, such as cataract surgery, were not excluded from the study.

Conclusion

This study provides valuable insights into the risks associated with anticoagulant therapy in glaucoma surgery, particularly when comparing warfarin to direct oral anticoagulants (DOACs). Our findings indicate that while patients on warfarin exhibited significantly higher risks of certain postoperative hemorrhagic complications, such as vitreous hemorrhage, conjunctival hemorrhage, and retinal hemorrhage, these complications did not translate into a greater likelihood of requiring secondary glaucoma surgeries, such as trabeculectomy revisions or aqueous shunt revision/repair. Because the hemorrhage types that were significant have relatively low risk of permanent vision loss, it may be beneficial to maintain patients on anticoagulant medication to prevent thromboembolic events, but this requires further research to confirm. It may be prudent to discuss an increased risk of bleeding with patients while reassuring them of the low incidence of vision-threatening complications.

These results underscore the importance of tailoring anticoagulation management for patients undergoing glaucoma filtration surgery, with a careful analysis of ocular versus systemic risks on an individual basis. The unique pharmacological properties of DOACs, including their more predictable pharmacokinetics and reduced need for monitoring compared to warfarin, likely contribute to their safer profile. While previous studies have established the efficacy and safety of DOACs in systemic conditions such as atrial fibrillation and venous thromboembolism, our study highlights their potential advantages in ocular surgery, a less studied area in the literature.

Future research can continue to analyze best practices for continuation vs cessation of anticoagulant medications before glaucoma surgery. Directly comparing the risk of hemorrhagic complications with anticoagulants to the risk of hypercoagulable states without anticoagulants will help to further refine perioperative management strategies and improve patient outcomes. In summary, our study furthers the consideration of types of anticoagulant use in glaucoma surgery patients and differential risks of hemorrhage and secondary surgery, to aid ophthalmologists in balancing the risks of thromboembolism and ocular hemorrhagic complications more effectively.

Disclosure

The authors report no conflicts of interest in this work.

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