Predictors of Long-term Ophthalmic Complications after Closed Globe Injuries Using the Intelligent Research in Sight (IRIS®) Registry

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Purpose: To identify clinical factors associated with the need for future surgical intervention following closed globe ocular trauma.

Design: Retrospective cohort study.

Subjects, Participants, and/or Controls: Patients in the American Academy of Ophthalmology Intelligent Research in Sight (IRIS®) Registry with a diagnosis of closed globe ocular trauma occurring between 2013 and 2019, identified using *International Classification of Disease, 10th Revision* and Systematized Nomenclature of Medicine codes.

Methods: Diagnosis codes were used to identify multiple concomitant diagnoses present on the date of closed globe ocular trauma. Survival analyses were performed for each outcome of interest, and linear regression was used to identify clinical factors associated with the risk of surgical intervention.

Main Outcome Measures: Outcomes included retinal break treatment, retinal detachment (RD) repair, retinal break treatment *or* RD repair, glaucoma surgery, and cataract surgery.

Results: Of the 206 807 patients with closed globe ocular trauma, 9648 underwent surgical intervention during the follow-up period (mean, 444 days): 1697 (0.8%) had RD repair, 1658 (0.8%) had retinal break treatment, 600 (0.3%) had glaucoma surgery, and 5693 (2.8%) had cataract surgery. Traumatic cataract was the strongest risk factor for cataract surgery (hazard ratio, 13.0; 95% confidence interval, 10.8–15.6), traumatic hyphema showed highest risk for glaucoma surgery (7.24; 4.60–11.4), and vitreous hemorrhage was the strongest risk factor for retinal break treatment and detachment repair (11.01; 9.18–13.2 and 14.2; 11.5–17.6, respectively) during the first 60 days after trauma date. Vitreous hemorrhage was a risk factor for cataract surgery at > 60 days after trauma date only. Iris–angle injury was the strongest risk factor for glaucoma surgery > 60 days after trauma, while vitreous hemorrhage remained the strongest factor for retinal break treatment and detachment repair at > 60 days. Traumatic hyphema was a risk factor for all surgical outcomes during all follow-up intervals.

Conclusions: Diagnosis of concomitant traumatic cataract, vitreous hemorrhage, traumatic hyphema, and other risk factors may increase the likelihood of requiring surgical intervention after closed globe ocular trauma. *Ophthalmology Science 2023;3:100237 © 2022 by the American Academy of Ophthalmology. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).*

Supplemental material available at www.ophthalmologyscience.org.

Ocular trauma is an important cause of visual impairment and blindness that can significantly impact the future quality of life.[1,2] Common mechanisms of trauma include blunt force, penetrating or perforating injury, and explosive blasts.[3] The Ocular Trauma Classification Group categorizes ocular trauma as either open or closed globe injuries; open globe injuries (OGIs) are characterized by a full-thickness wound of the eye wall that includes the cornea, sclera, or both, while closed globe injuries are either contusions of the globe or lamellar lacerations.[4]

Open globe injuries are generally more severe than closed globe ocular trauma, with longer hospitalizations and worse visual prognosis,[5] and an extensive body of literature has further characterized associated complications such as traumatic hyphema,[6] vitreous hemorrhage,[7] endophthalmitis,[8] traumatic cataract,[9,10] and need for additional surgical intervention.[11] Quantitative tools such as the Ocular Trauma Score and the Retinal Detachment after Open Globe Injury Score have been developed to predict visual outcomes and likelihood of retinal detachment (RD) after OGI, respectively.[12,13,14,15]

While OGIs often portend worse visual outcomes, closed globe ocular trauma is more common and can also result in severe loss of vision, as the force of injury is largely

transmitted to the structures of the eye without an opportunity for release.[16] This subsequent compression and expansion of the globe can damage the anterior segment, causing hyphema,[6,17−19] injury to the iris−angle[17,20] and traumatic cataract,[9,21] and the posterior segment, resulting in vitreous hemorrhage,[7,22,23] retinal hemorrhage,[24] retinal tears and detachments,[25] choroidal injury,[24] and traumatic optic neuropathy.[20] Compared with OGIs, far fewer studies have evaluated closed globe ocular trauma in a systematic fashion, with the existing literature largely confined to military and pediatric populations.[18,26] No prognostic tools equivalent to the Ocular Trauma Score or the Retinal Detachment after Open-Globe Injury Score exist for closed globe trauma, and little has been written regarding the characteristics of closed globe ocular trauma that predict the need for surgical intervention, which limits clinicians' ability to appropriately counsel patients presenting with these injuries.

The United States Eye Injury Registry is a nonprofit organization that collected data on serious eye trauma between 1988 and 2003 and helped to provide insight into the epidemiology, risk factors, and outcomes of OGI and, in a more limited fashion, closed globe trauma, but it has been inactive since 2013.[13,27,28] In the absence of an active registry devoted to eye injuries, we used the American Academy of Ophthalmology Intelligent Research in Sight (IRIS®) Registry, a national database containing electronic health record data from 65 million unique patients and thousands of participating eye care providers to study closed globe ocular trauma.[29] This comprehensive database has been employed in a variety of research domains including epidemiological reporting and biomarker discovery, as well as risk factor and practice pattern analysis.[30−33] In this study, we evaluated patients with closed globe ocular trauma within the IRIS Registry in order to identify baseline clinical factors associated with various ophthalmic complications, including the need for and timing of future surgical intervention.

Methods

This study was conducted in accordance with the Declaration of Helsinki.[34] Given the use of deidentified patient data, this study was exempted from review by the University of Washington Institutional Review Board. Data collection and aggregation methods used for the IRIS Registry database have previously been described.[31,35] Version 2021_04_16 of the IRIS Registry was used for this analysis.

Study Patient Population

Patients in the IRIS Registry aged ≥ 18 years with a history of closed globe ocular trauma between 2014 and 2019 were included. Closed globe ocular trauma was defined using International Classification of Disease, 9th (ICD-9) and 10th (ICD-10) Revisions and Systematized Nomenclature of Medicine codes that were selected to represent a broad range of blunt trauma in and around the eye (Table S1, available at https://www.ophthalmologyscience.org). The trauma date was defined as the earliest date with a closed globe ocular trauma code. Patients were excluded if they also had diagnosis code(s) corresponding to a penetrating injury or various OGIs on the date of trauma (Table S1, Exclusion Criteria). Patients with a history of retinal break treatment, RD repair, cataract surgery, or glaucoma surgery prior to the closed globe ocular trauma date were also excluded from models of corresponding outcomes (Table S1, Prior Conditions). We determined whether the trauma was unilateral or bilateral. If unilateral, the trauma eye was defined as the eye with the trauma diagnosis; if bilateral, a random eye was selected as the trauma eye. Censor date was defined as the latest date of available medical records without the outcome of interest. The IRIS Registry does not include birth year information for patients with ages > 87 years. We therefore treated patients > 87 years of age as a single category.

Outcomes of Interest

Outcomes of interest included retinal break treatment, RD repair, retinal break treatment *or* RD repair, glaucoma surgery, and cataract surgery. Participants were identified as having an outcome of interest if they had a Current Procedural Terminology code corresponding to one of these procedures in the trauma eye after the trauma date (Table S1, Outcomes). To review how risk changed over time, we used a split-time approach for the outcomes of interest. For all outcomes, we used a split of 60 days. Early complications occurred within 0 to 60 days and late outcomes occurred > 60 days after the ocular trauma date. Sixty days was selected after an initial review of survival curves for the outcomes of interest to encompass an initial period of higher risk of events, and a sensitivity analysis was performed to confirm that results were robust across selection of the cutoff point. Participants who had same-day bilateral cataract surgery were excluded. Survival curves evaluating the time to cataract surgery after the trauma event were calculated for both the trauma eye and the fellow eye from participants with unilateral trauma and no prior history of cataract and compared using a cox proportional hazards model to assess whether rates of cataract surgery were higher than expected after trauma.

Covariates

We identified concomitant conditions as covariates for modeling based on diagnosis codes present on the date of trauma in the trauma eye (Table S1, Concurrent Diagnoses). Concomitant conditions included corneal edema or opacity, traumatic hyphema, iris−angle injury, traumatic cataract, lens displacement, vitreous hemorrhage, retinal break, RD, commotio retinae, macular scar, macular hole, choroidal injury, and optic nerve injury. Additional covariates included age on the trauma date, birth sex, and self-reported race and ethnicity.

Statistical Analysis

We performed survival analyses via time-split Cox regression for each outcome of interest. We performed a univariate regression for each covariate (concomitant conditions and demographic variables) and selected features with $P \leq 0.1$ to be included in the multivariate regressions. All reported results are from the multivariate models. All statistical analyses were performed with R statistical software version 3.6.1 (R Foundation for Statistical Computing). For retinal break treatment, RD repair, and retinal break treatment or RD repair, we excluded patients with a prior or concomitant retinal break or RD diagnosis. For the glaucoma surgery outcome, we excluded patients with prior glaucoma surgery. For the cataract surgery outcome, we excluded patients with prior cataract surgery.

Results

A total of 206 807 patients were diagnosed with closed globe ocular trauma between 2014 and 2019 and met the inclusion and exclusion criteria (Fig 1). There was a slight female preponderance in the overall study group, with 106 252 female patients (51.4%) (Table 1). The most common concurrent diagnoses at presentation were hyphema in 17 027 patients (8.2%), vitreous hemorrhage in 6107 (3.0%), corneal edema in 3818 (1.9%), RD in 3765 (1.8%), and retinal break in 2778 (1.3%) (Table 2).

Of the 206 807 patients, 1697 (0.8%) patients ultimately underwent RD repair, 1658 (0.8%) patients underwent retinal break treatment, 3219 (1.56%) patients required retinal break or RD repair, 600 (0.3%) patients underwent glaucoma surgery, and 5693 (2.8%) patients underwent cataract surgery after their closed globe ocular trauma event (Table 2). The proportions of men who underwent cataract surgery, glaucoma surgery, retinal break treatment, and RD repair were 50.1%, 57.3%, 67.9%, and 74.0% respectively.

The available follow-up periods for patients had a mean of 444 days, a median of 211 days, and an interquartile range of 6 to 760 days.

Cataract Surgery

The diagnoses of traumatic cataract, traumatic hyphema, and iris—angle injury at presentation with closed globe ocular trauma were all risk factors for subsequent cataract surgery at early and late follow-up periods. The strongest risk factor was traumatic cataract, with a hazard ratio (HR) of 13.0 (95% confidence interval [CI], 10.8—15.6) for cataract surgery in the first 60 days after blunt trauma and 4.78 (CI, 3.91—5.84) after 60 days. Lens displacement increased the risk of cataract surgery in the first 60 days (HR, 5.03; CI, 4.05—6.25) but not at later follow-up periods, while traumatic hyphema was a risk factor in the first 60 days (HR, 2.48; CI, 2.18—2.82) and after 60 days (HR, 2.48; CI, 2.26—2.72). Overall, there was a higher risk of needing cataract surgery in the eye with closed globe ocular trauma compared to the fellow eye (HR, 1.49; CI, 1.43—1.55) (Fig 2).

Glaucoma Surgery

Patients with closed globe trauma were at the highest risk of requiring glaucoma surgery at all time periods if they presented with traumatic hyphema; this risk was the greatest within the first 60 days (HR, 7.24; CI, 4.60—11.4). Iris—angle injury was a risk factor for requiring glaucoma surgery after 60 days (HR, 4.52; CI, 2.56—7.97). Corneal edema was a risk factor for glaucoma surgery early (HR, 2.85; CI, 1.29—6.28) but not at the late time period (Fig 2).

Retinal Break and RD

Vitreous hemorrhage at presentation was the strongest risk factor for all posterior segment outcomes in both the early (0—60 days) and late (> 60 days) follow-up periods. Patients who presented with vitreous hemorrhage with their closed globe ocular trauma were at increased risk of requiring retinal break treatment (HR, 11.0; CI, 9.18—13.2), RD repair (HR, 14.2; CI, 11.5—17.6), and retinal break treatment *or* RD repair (HR, 12.3; CI, 10.7—14.2) during the early follow-up period. In the late follow-up period, vitreous hemorrhage continued to be a significant risk factor for all posterior segment outcomes, although to a lesser degree than in the first 60 days. The presence of traumatic hyphema, traumatic cataract, lens displacement, and choroidal injury were risk factors for RD for both early and late follow-up periods after closed globe trauma. After vitreous hemorrhage, traumatic hyphema at presentation was the next greatest risk factor for RD repair, with a HR of 4.09 (CI, 3.33—5.02) early and 3.43 (CI, 2.67—4.41) late. For retinal break treatment *or* RD repair combined, the presence of traumatic hyphema and choroidal injury were also risk factors for both early and late follow-up periods, while commotio retinae was only a risk factor for the early follow-up period, and lens displacement was only a risk factor for the late follow-up period (Figs 3—5).

Discussion

For patients in the IRIS Registry with closed globe trauma, traumatic hyphema was the most common concurrent diagnosis at presentation (8.2%) and a significant risk factor for all surgical outcomes during all follow-up intervals. The most common surgical intervention was cataract surgery (2.8%), followed by retinal break treatment (0.8%), RD repair (0.8%), and glaucoma surgery (0.3%). Overall, there was no male predominance in patients with closed globe trauma, and unlike OGI, the rate of surgical intervention after closed globe trauma was low.

Our findings differ from previous studies, although current literature on closed globe trauma is severely limited. In one study of > 5000 patients with closed globe ocular trauma, 6.7% required surgery.[18] Another study in 46 patients who all required surgery after closed globe injury found that RD repair was the most common procedure (72%).[25] While no other study in the literature evaluates procedural interventions after closed globe ocular trauma in as comprehensive of a fashion, the percentage of patients requiring surgery after closed globe trauma in our study was far lower than previously reported for OGI, where up to 45% of patients required follow-up surgeries.[11] Although this can in part be explained by the increased overall severity of OGIs, it is also a reflection of the diversity of closed globe ocular trauma and the broad range of diagnosis codes used in this study to define it, unlike the very specific diagnosis criteria that exist for OGI.

Unlike other ocular trauma studies where the male to female ratio was as high as 7:1, we found a slight female predominance (51.4%) among patients who met the inclusion criteria.[23,36—39] This discrepancy could be a function of prior studies selecting for more serious eye injuries by focusing on injuries that have the potential of causing permanent vision loss, permanent change in eye anatomy, or both, or only evaluating patients who present to the emergency department or are hospitalized after eye trauma. The IRIS Registry is composed of patients followed by
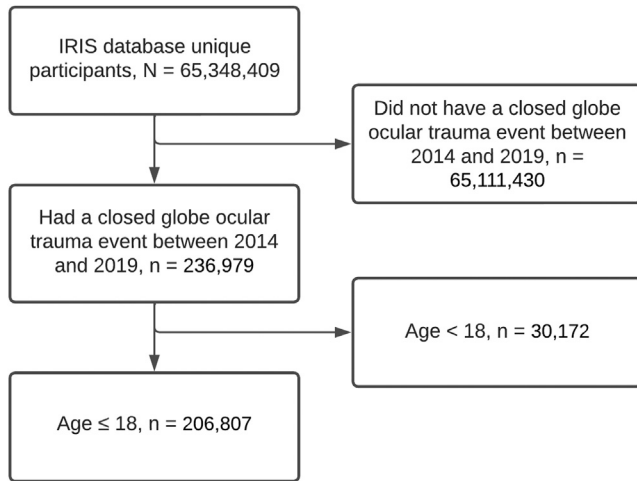
Figure 1. Patient selection flowchart. IRIS = Intelligent Research in Sight.

ophthalmologists predominantly in the ambulatory setting; while patients with serious eye injuries can present as outpatients, it is reasonable to presume that the overall injury severity is lower compared to those presenting to a hospital. When we analyzed only the patients who required surgical

Table 1. Demographic Information

	Total (N = 206 807)
Patients < 87 years, n (%)	188 625 (91.21)
Mean (SD)	55.46 (18.65)
Median	59
Q1−Q3	41−71
Min-max	18−86
Patients ≥ 87 years, n (%)	18 182 (8.79)
Gender	
Female	106 252 (51.38)
Male	99 779 (48.25)
Not reported	776 (0.38)
Race	
White	141 603 (68.47)
Black or African American	16 832 (8.14)
Asian	5149 (2.49)
Other	2313 (1.12)
Unknown	40 910 (19.78)
Ethnicity	
Not Hispanic or Latino	149 342 (72.21)
Hispanic or Latino	15 029 (7.27)
Unknown	42 436 (20.52)
Insurance	
Medicare	78 104 (37.77)
Commercial	71 648 (34.64)
Missing	30 937 (14.96)
Medicare_Advantage	13 138 (6.35)
Medicaid	6789 (3.28)
Other	6191 (2.99)
Trauma Eye	
Left	99 491 (48.11)
Right	95 283 (46.07)
Bilateral	12 033 (5.82)

Q = quartile; SD = standard deviation.

Table 2. Patient Clinical Characteristics, Past History, Concurrent Diagnoses, and Outcomes

		Total (N = 206 807)
Visual acuity (logMAR)	Mean (SD)	0.66 (0.86)
(Snellen)		20/91 (20/145)
Intraocular pressure (mmHg)	Mean (SD)	15.54 (4.92)
Prior history n (%)		
Prior retinal break or retinal detachment		3908 (1.89)
Prior glaucoma surgery		23 082 (11.16)
Prior cataract surgery		523 (0.25)
Concurrent diagnoses, n (%)		
Traumatic hyphema		17 027 (8.23)
Vitreous hemorrhage		6107 (2.95)
Corneal edema		3818 (1.85)
Retinal detachment		3765 (1.82)
Retinal break		2778 (1.34)
Iris—angle injury		1302 (0.63)
Commotio retinae		1185 (0.57)
Lens displacement		1125 (0.54)
Traumatic cataract		1136 (0.55)
Macular hole		1245 (0.6)
Choroidal injury		922 (0.45)
Macular scar		434 (0.21)
Optic nerve injury		277 (0.13)
Outcomes, n (%)		
Retinal detachment repair		1697 (0.82)
Retinal break treatment		1658 (0.8)
Retinal break treatment or retinal detachment repair		3219 (1.56)
Glaucoma surgery		600 (0.29)
Cataract surgery		5693 (2.75)

logMAR = logarithm of the minimum angle of resolution; SD = standard deviation.

intervention after a blunt trauma diagnosis, the male to female ratio was higher in this group, in agreement with other literature. We found a higher male to female ratio in patients requiring glaucoma surgery (57.3% male), retinal break treatment (67.9% male), and RD repair (74.0% male) after the blunt trauma diagnosis.

We found several risk factors associated with subsequent cataract surgery following closed globe trauma. Traumatic cataract at presentation was the strongest risk factor for cataract surgery after closed globe ocular trauma at early and late follow-up periods. Lens displacement at presentation was a significant risk factor up until 60 days after trauma but was no longer significant afterward. A direct comparison to prior studies is challenging, as little of the existing literature on traumatic cataracts focuses solely on closed globe ocular trauma, timing of cataract surgery after closed globe ocular trauma has not been discussed, and the literature rarely describes clinical features that are present at the time of initial injury, only the indications that prompted surgery. Studies that included patients with closed globe ocular trauma and OGIs are mostly in the pediatric or military populations[9,40−42]; indications for surgery also included traumatic cataract and lens subluxation or dislocation in these patient groups. A retrospective review of 24 eyes with closed globe injury that underwent vitrectomy,

A

B
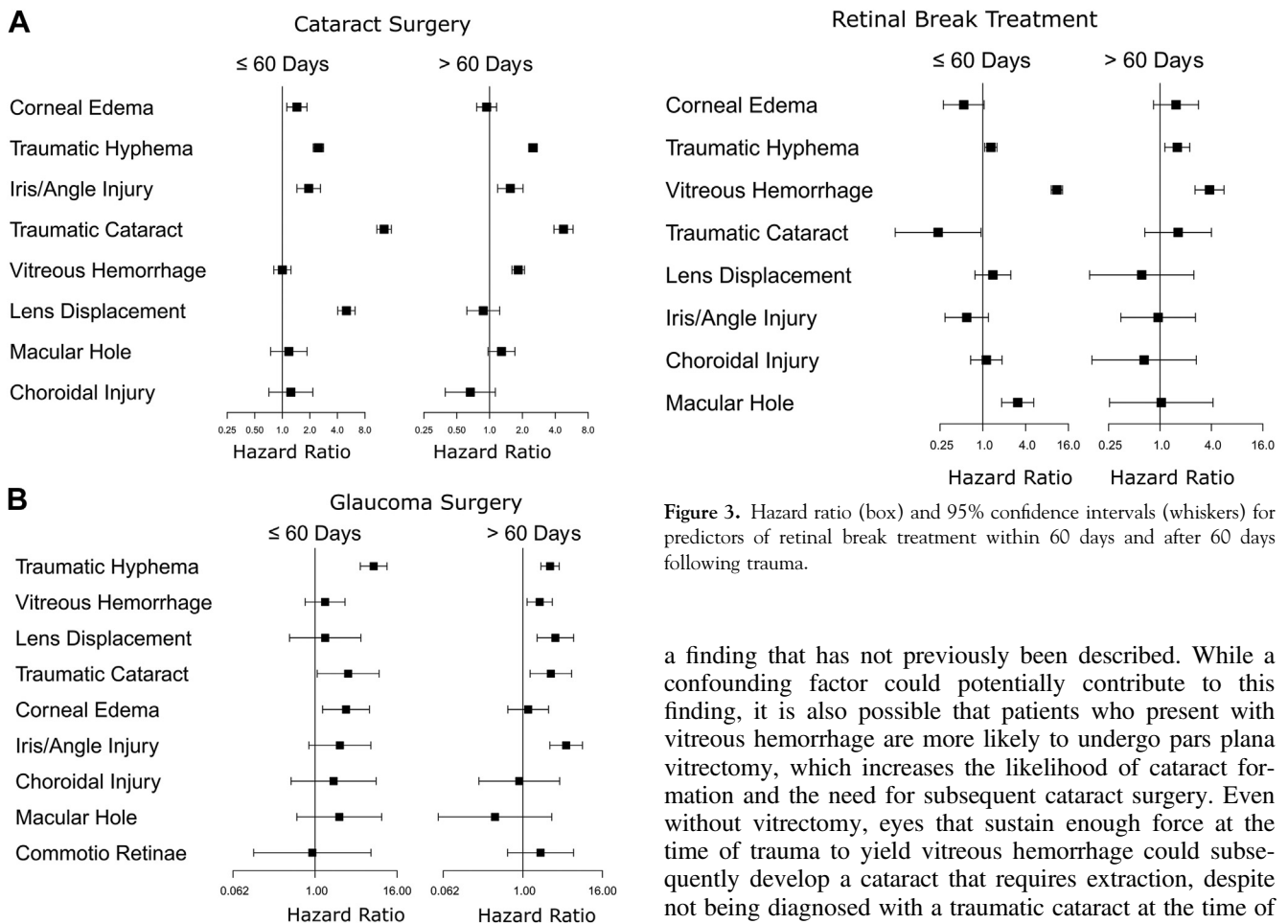
Figure 2. Hazard ratio (box) and 95% confidence intervals (whiskers) for cataract surgery (**A**) and glaucoma surgery (**B**) occurring within 60 days and after 60 days following trauma.

Figure 3. Hazard ratio (box) and 95% confidence intervals (whiskers) for predictors of retinal break treatment within 60 days and after 60 days following trauma.

lensectomy, and scleral fixation of intraocular lens also described traumatic cataract and lens subluxation as the primary indication for surgery in all eyes.[21]

Traumatic hyphema was another risk factor for cataract surgery at early and late follow-up periods. This finding supports prior studies that have demonstrated an association between traumatic hyphema and traumatic cataract, although the majority of these studies group OGI and closed globe ocular trauma patients in their analysis. A retrospective review of 168 eyes with hyphema (64 from closed globe ocular trauma and 104 from OGI) noted an association with traumatic cataract formation, with 78 eyes ultimately requiring either pars plana lensectomy or phacoemulsification for cataract removal.[6] Another review of 44 patients with traumatic hyphema solely from closed globe ocular trauma described cataract in 20.6% of patients; however, the need for surgical intervention was not included in this study.[43]

Unexpectedly, vitreous hemorrhage on presentation after closed globe ocular trauma was an independent risk factor for cataract surgery even after controlling for traumatic cataract and traumatic hyphema at the late follow-up period,

a finding that has not previously been described. While a confounding factor could potentially contribute to this finding, it is also possible that patients who present with vitreous hemorrhage are more likely to undergo pars plana vitrectomy, which increases the likelihood of cataract formation and the need for subsequent cataract surgery. Even without vitrectomy, eyes that sustain enough force at the time of trauma to yield vitreous hemorrhage could subsequently develop a cataract that requires extraction, despite not being diagnosed with a traumatic cataract at the time of presentation.

Of the procedural interventions evaluated in our study, glaucoma surgery was the least commonly performed, with 0.3% of patients requiring glaucoma surgery after their closed globe ocular trauma. A concomitant diagnosis of hyphema at the time of trauma was an independent risk factor at early and late follow-up periods, and iris–angle injury was a risk factor at the late period, but not in the first 60 days. Girkin et al[28] found the overall incidence of glaucoma after blunt ocular trauma was 3.4% in the United States Eye Injury Registry and described hyphema, lens injury, and angle recession as independent risk factors for glaucoma development, but the need for surgical interventions was not evaluated. Of note, the United States Eye Injury Registry is composed of patients with severe eye injuries (including OGIs) that are likely to result in permanent structural damage functional loss. or both; as such, the incidence of pathology in this population is expected to be greater than that of a comprehensive database like the IRIS Registry. Ozer et al reviewed 105 eyes of 102 patients with blunt or penetrating ocular trauma and found that 12% of eyes with blunt trauma required glaucoma surgery. Hyphema, OGI, corneal injury, poor visual acuity, and optic atrophy were independently associated with needing glaucoma surgery for their combined cohort of open and closed globe injury patients.[20]
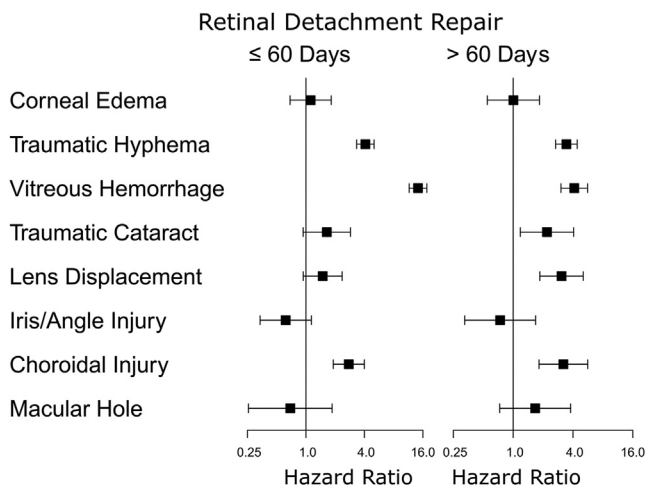
Retinal Detachment Repair

≤ 60 Days   > 60 Days

Figure 4. Hazard ratio (box) and 95% confidence intervals (whiskers) for predictors of retinal detachment repair within 60 days and after 60 days following trauma.

Treatment for retinal break or RD was the second most common surgical outcome in this study, with 1.5% of patients requiring either retinal break treatment or RD repair. Although there is no directly analogous study of closed globe ocular trauma patients, other authors have described posterior segment manifestations of blunt trauma. Erdurman et al[23] performed a retrospective review of 115 patients with contusion injuries of the posterior segment and found RD in 31% of cases, which was the most common indication for surgery in their study. As patients in their cohort were mostly referred to their tertiary center for vitreoretinal surgery, their high rate of RD is unsurprising. Another study of 445 eyes with blunt ocular trauma found RD in 194 eyes (43%); a similar referral bias was present in this study as well.[44]

Retinal Detachment Repair or Retinal Break Treatment

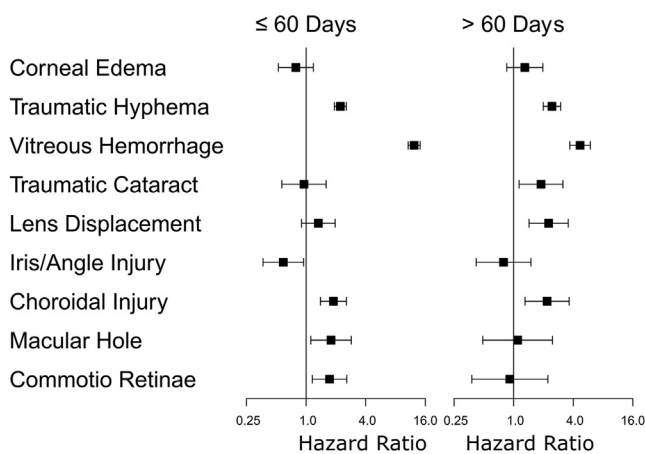≤ 60 Days   > 60 Days

Figure 5. Hazard ratio (box) and 95% confidence intervals (whiskers) for predictors of retinal detachment repair or retinal break treatment within 60 days and after 60 days following trauma.

Vitreous hemorrhage at presentation was the strongest risk factor for retinal break treatment or RD repair at both early and late follow-up periods in our study. In their analysis of 33 eyes with severe vitreous hemorrhage after closed globe injury, Yeung et al[22] found retinal tears in 18% of eyes and RDs in 18% of eyes; the authors noted that many tears were not discovered until after the retina detached. Our study reaffirms the need for patients with vitreous hemorrhage after blunt eye trauma to be followed closely even if they do not have a retinal tear or RD on presentation, as they are at risk for future development of retinal pathology.

In our study, traumatic hyphema after closed globe ocular trauma was the only concomitant diagnosis that was a significant risk factor for each of the outcomes at any follow-up time period. The majority of the traumatic hyphema literature focuses on the increased risk of ocular hypertension and glaucoma after injury,[17,19,20,28] although some studies do include the risk of cataract development and RD as previously discussed.[6,43] Nearly 40% of patients who present with traumatic hyphema can develop ocular hypertension, and follow-up schedules and risk stratification tools have been proposed to help identify patients who might require intervention for elevated intraocular pressure.[17,45] However, our data suggest that in addition to regular intraocular pressure monitoring and gonioscopy to assess for angle recession, patients who present with hyphema after blunt ocular trauma should also be counseled regarding their increased risk of retinal break and RD both early (0−60 days after trauma) and late (60 days after trauma) and undergo dilated fundus examination for posterior segment monitoring.

Our study had several limitations. While the IRIS Registry is composed of entries from both private ophthalmology practices and academic centers, there are relatively fewer academic centers represented by the database. Currently, one third of member academic institutions of the Association of University Professors of Ophthalmology participate in the IRIS Registry (Lum F, personal communication, 2022). Despite the increase in the involvement of academic centers, some of the most severe ocular trauma cases might not be captured in our current study population. Our results were dependent on accurate and comprehensive coding of clinicians for patient diagnoses and procedures. However, we selected a wide range of ICD-9, ICD-10, and Systematized Nomenclature of Medicine codes to represent blunt periocular and ocular trauma (Table S1) to increase the likelihood that the concomitant diagnoses noted in the IRIS Registry database for each patient were associated with a trauma event. This was necessary because in many instances, the ICD-9, ICD-10, and Systematized Nomenclature of Medicine codes alone do not specify whether the diagnosis is secondary to trauma. For example, ICD-10 codes for hyphema (H21.00, H21.02, H21.02, H21.03) do not differentiate between hyphema due to trauma versus hyphema due to anterior segment neovascularization. However, a diagnosis of hyphema made on the same day as the diagnosis of an eyelid contusion (S00.10XA, S00.11XA, S00.12XA) can reasonably be presumed to be a traumatic hyphema. It is

possible that we are missing patients with closed globe injury using this methodology if their provider did not use one of the blunt ocular trauma codes we specified in the inclusion criteria and instead only coded for the concomitant diagnoses (e.g., a hyphema). Despite this possibility, it was more important to exclude patients without history of trauma from the data set for our analysis. We also acknowledge that some patients who met the inclusion criteria for this study but did not carry a concomitant diagnosis might not have had an injury to the eyeball itself but may have only had, for example, an isolated orbital fracture or eyelid injury. Our main clinical question was to identify diagnoses on presentation that increased the risk of patients needing surgical intervention after blunt trauma in and around the eye. We believe that the clinical utility of our results persists; patients with history of blunt ocular or periocular trauma, such as an orbital fracture, and concomitant hyphema are at increased risk of requiring one of the procedural outcomes than patients with an orbital fracture alone.

Another limitation of this study is the inability to attribute causation of the surgical outcomes to the trauma event. Although the appropriate eye and chronology of blunt ocular trauma diagnosis code and surgical outcome were selected, it is possible that the patient needed surgery for an indication unrelated to their history of trauma. This is particularly true for cataract surgery, as it is a very commonly performed procedure as patients age. However, patients who underwent cataract surgery after their trauma were nearly 50% more likely to have surgery in the traumatized eye than their contralateral eye; if cataract surgery were completely unrelated to trauma and simply secondary to age, one would expect a more even distribution of surgery between the eyes. Overall, we were reassured that the risk factors identified for each procedure were clinically relevant and also aligned with those previously discussed in the literature. Diagnostic codes also do not contain the granularity needed to describe the severity of a particular diagnosis that occurred concomitantly with a patient's closed globe trauma; for example, the presence, degree, and duration of intraocular pressure elevation certainly factor into the decision to perform an anterior chamber washout for a patient with hyphema; however, these details are not present in the IRIS Registry and therefore are not a component of this study.

Based on the evaluation of > 200 000 patients diagnosed with closed globe trauma in the IRIS Registry, we found that traumatic cataract, traumatic hyphema, and vitreous hemorrhage at presentation are associated with higher risks of developing complications requiring surgical intervention. We believe our results provide valuable information for clinicians caring for patients with blunt ocular trauma by identifying which diagnoses at presentation increase the likelihood of requiring surgical intervention at various periods of time in the largest study group to date. Future directions of the study should include predictors of visual acuity outcomes after closed globe trauma. The addition of other more detailed databases such as those based on large, multicenter electronic health records would allow for additional risk stratification of patients, particularly those with hyphema at presentation, in order to better characterize which patients will ultimately require anterior segment, posterior segment procedures, or both.

Footnotes and Disclosures

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