Graefe's Archive for Clinical and Experimental Ophthalmology (2023) 261:3031–3039
https://doi.org/10.1007/s00417-023-06087-0

TRAUMA

# Association of open globe injury characteristics with outcome measures in the emergency department

**Justin K. Tram[1] · Siri P. Yalamanchili[1] · Ashar Ata[2] · Denis R. Pauze[2] · Edward J. Wladis[1,3]**

Received: 17 October 2022 / Revised: 12 April 2023 / Accepted: 21 April 2023 / Published online: 2 May 2023


## Abstract

**Purpose** To evaluate the association of demographic and clinical features of emergency department (ED) patients presenting with open globe injuries (OG) with outcomes such as inpatient admission rate, length of stay (LOS), and total cost.

**Methods** The Nationwide Emergency Department Sample database 2018 and 2019 was used to analyze the association of demographic and clinical features of OG patients with outcome measures.

**Results** 8404 OG patients were identified. Medicaid patients were associated with higher ED costs and a higher frequency of extended LOS. The 70+ age group was associated with higher inpatient admission. Frail patients were associated with significantly increased likelihood of inpatient admission, higher likelihood of extended LOS and higher total combined ED cost. Falls and being struck were associated with shorter LOS.

**Conclusion** This study describes the most common demographic and clinical characteristics of OGIs that present to the ED, as well as the association of these characteristics with outcome measures such as inpatient admission rates, LOS, and total cost. The study further identified potential high-risk patients for prolonged length of stay. The findings will better optimize patient care protocols to improve outcomes.

**Keywords** Open globe injuries · Risk factors · Demographics · Traumatic eye injury · Outcome measures

**Key messages**

***What is known:***

- Previous studies examining population characteristics of open globe injuries (OG) in the emergency department (ED) up to 2014 have found certain demographics such as low-income males to be more highly associated with open globe injuries.

***What is New:***

- This study describes the 2018-2019 demographic and clinical features of ED patients presenting with OG, identifying characteristics such as low-income and frailty to be associated with longer length of hospital stay.
- The study identifies warmer months to be associated with increased prevalence of OG, but lower ED costs.

✉ Edward J. Wladis
wladise@amc.edu

[1] Ophthalmic Plastic Surgery, Lions Eye Institute, Department of Ophthalmology, Albany Medical College, Albany (Slingerlands), New York, USA

[2] Department of Emergency Medicine, Albany Medical College, Albany, New York, USA

[3] Department of Otolaryngology, Albany Medical College, Albany, New York, USA

## Introduction

Ocular trauma is one of the leading causes of blindness in the United States, with an average annual incidence of 2-2.4 million cases [1]. Open globe injuries (OGIs) account for some of the worst outcomes, requiring emergent surgical repair to prevent poor visual outcomes [2]. While OGIs comprise

only 2% of annual ophthalmic trauma, they account for up to 44% of all costs related to ocular trauma [3].

Previous investigations used data from 2006 to 2014 to define common characteristics of patients with OGI that present to the Emergency Department (ED) [4, 5] and features that are associated with an increased odds of inpatient admission [4]. These studies have pointed to low income males as the most at-risk group, with increased severity of trauma associated with increased rates of inpatient admission [4].

This study aims to update the existing literature using data from 2018 and 2019 and to examine the association of demographic and clinical characteristics with outcomes such as inpatient admission rate, length of stay, and total cost. Knowledge of factors affecting clinical outcome metrics may assist in the development of a risk stratification tool based on these factors to help guide emergency department decision making. Furthermore, identification of key features that suggest increased cost and consumption of hospital resources may serve to inform resource allocation.

## Methods

### Database

The US Nationwide Emergency Department Sample (NEDS) data from 2018 and 2019 was queried to explore cases of OGI that presented to emergency departments. NEDS is the largest national public ED database, sponsored by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project (HCUP), and provides a 20% stratified sample of U.S hospital-owned EDs. This approach extrapolates data that is based on factors such as geographic region, trauma center designation, urban-rural status, teaching status, and hospital ownership structure to create a national estimate of ED visits.

This project was deemed exempt from review or approval by the Albany Medical College Institutional Review Board and adhered to the Declaration of Helsinki and the tenets of the Health Information Portability and Accountability Act. Informed consent was not required for use of this publicly available deidentified dataset.

### Study design

Diagnoses in the NEDS database use the International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM) system. The first diagnosis listed for each visit is considered the primary diagnosis and characterizes the primary condition of the patient that necessitated the ED visit. All subsequent diagnoses labeled after the primary diagnosis are termed secondary diagnoses and were considered to be concomitant diagnoses.

This study used ICD-10-CM codes to identify a cohort of patients presenting to the ED with a primary diagnosis of open globe injuries during 2018 and 2019 (Table 1). The investigation also employed the Hospital Frailty Risk Score (HFRS) as an aggregate of the most important systemic concomitant diagnoses that could affect patient outcomes. The HFRS is a well-vetted metric that defines the overall health of a patient; higher scores are independently associated with worse patient outcomes after various surgical and medical interventions [6]. An HFRS score was calculated for each patient using ICD-10-CM codes in the same methodology as outlined in previous studies [6]. Previous studies using HFRS have determined a HFRS cutoff of $\geq 5$ to define patients as frail, [7, 8] and, as such, the current investigation employed a cutoff of $\geq 5$ in our characterization of each patient as either frail or non-frail.

Age was categorized into groups of 0-17 years, 18-29 years, 30-39 years old, 40-49 years old, 50-59 years old, 60-69 years old, and 70+ for better comparison to age categories that were utilized in previous studies [4]. Inpatient cases were sorted into either extended or nonextended lengths of stay with a length of greater than or equal to three days corresponding to an extended stay. Patients with ED costs of exactly 1,000,000 were excluded from the study due to the extensive number of documentation errors in those cases. When analyzing inpatient admission frequency, this study examined only non-transferred patients, sorting them into groups of either admitted to same hospital or discharged from same hospital.

### Statistical analysis

Statistical analysis was conducted using R, version 4.03 (R Foundation for Statistical Computing, Vienna, Austria). A modified Poisson was used to analyze the association of characteristics with inpatient admission frequency and extended length of stay. Negative binomial regression was performed to examine the association of various characteristics with total ED associated cost. A parsimonious backwards selection model was utilized in creating the modified Poisson and the negative binomial regression models. Other patient and hospital demographic factors were controlled during regression analysis. Incident risk ratios were described with 95% confidence intervals. In order to compensate for possible alpha inflation, statistical significance was set at 0.01.

## Results

Over the two-year period of 2018 and 2019, the query identified 8,404 open globe injury patients who presented to the ED in the United States.

**Table 1** Demographic Characteristics

| DEMOGRAPHICS | Open Globe Injuries |
|---|---|
| Number | 8404 |
| Average Age (Mean ± SD) | 40.38 ± 24.28 |
| Age Categories: | |
| 0-17 | 1640 (19.6%) |
| 18-29 | 1437 (17.1%) |
| 30-39 | 1183 (14.1%) |
| 40-49 | 1091 (13%) |
| 50-59 | 1068 (12.7%) |
| 60-69 | 783 (9.3%) |
| 70+ | 1180 (14.1%) |
| Female | 2369 (28.2%) |
| Race | |
| White | 3928 (52.6%) |
| Black | 1693 (22.7%) |
| Hispanic | 637 (21.9%) |
| Asian or Pacific Islander | 208 (2.8%) |
| Native American | 28 (0.4%) |
| Other | 354 (4.7%) |
| Weekend | 2588 (30.8%) |
| Month | |
| January | 687 (8.2%) |
| February | 528 (6.3%) |
| March | 614 (7.3%) |
| April | 665 (7.9%) |
| May | 840 (10%) |
| June | 710 (8.5%) |
| July | 724 (8.6%) |
| August | 974 (11.6%) |
| September | 684 (8.1%) |
| October | 747 (8.9%) |
| November | 616 (7.3%) |
| December | 610 (7.3%) |
| Payer | |
| Medicare | 1607 (19.1%) |
| Medicaid | 2040 (24.3%) |
| Private | 2455 (29.2%) |
| Self-pay | 1399 (16.6%) |
| No charge | 54 (0.6%) |
| Other | 849 (10.1%) |
| Income Quartile | 3018 (35.9%) |
| $1–$45,999 | 2211 (26.3%) |
| $46,000– $58,999 | 1769 (21%) |
| $59,000–$78,999 | 1406 (16.7%) |
| $79,000+ | |
| Urban Location | 7799 (92.8%) |
| Hospital Region | |
| Northeast | 1219 (14.5) |
| Midwest | 1879 (22.4) |
| South | 3549 (42.2) |
| West | 1757 (20.9) |
| Hospital Type | |
| Metropolitan Non-teaching | 1569 (18.7%) |
| Metropolitan Teaching | 5971 (71%) |
| Non-metropolitan | 864 (10.3%) |
| Hospital Trauma Level | |
| Nontrauma Center | 3253 (39%) |
| Level I | 2841 (34.1%) |
| Level II | 1421 (17%) |
| Level III | 823 (9.9%) |
| Patient Disposition | |
| Discharged from ED | 6364 (75.7%) |
| Admitted to Same Hospital (Inpatient) | 1079 (12.8%) |
| Transferred to Other Hospital/Died in ED/ Not Admitted/Unknown Destination | 961 (11.4%) |

## Demographics

Males (71.2%) and those in the lowest income quartile (35.9%) constituted the highest proportion of OGI patients (Table 1). The mean age was 40 years, with the 0-17 age group comprising the largest proportion (19.6%) (Table 1). Private insurance (29.2%) predominated in the group.

Because race as a variable was added in the 2019 edition of NEDS, race was only analyzed for that year. White was the most common race amongst OGI patients (52.6%), followed by Black race (22.7%) and Hispanic race (21.9%).

## Details of arrival

There was an increased prevalence of presentation in the ED during warmer months (May-August), but no predilection for either weekdays or weekends (Table 1). The majority of ED visits occurred at metropolitan teaching hospitals (71%), with 34.1% of visits occurring at Level I trauma centers, 17% of visits occurring at Level II trauma centers, and 9.9% occurring at Level III trauma centers. 75.7% of all patients were discharged without admission to the hospital, whereas 12.8% of patients were admitted to inpatient care (Table 1). Table 7 outlines the distribution of total cost, inpatient cost, and LOS. Table 8 further details the proportions of inpatient admissions and discharges from the ED, as well as LOS. Figures 1 and 2 graphically demonstrate the distribution related to inpatient cost, total cost, and LOS.

## Injury characteristics

96.8% of patients presented with an injury related diagnosis, with multi-injury composing only 33.5% of the cohort

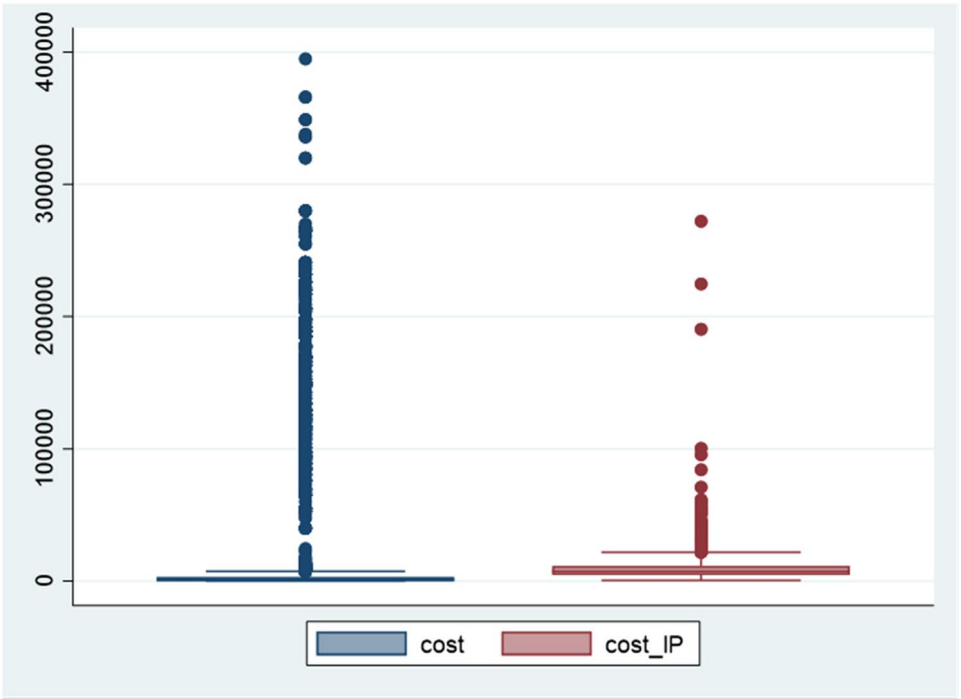


**Figure 1:** Histograms of Inpatient Cost ("cost_IP") and Total Cost ("cost")

(Table 2). Struck (37.6%) was the most common mechanism of injury in the cohort, followed by falls (18.6%) and cuts (9.8%). The most common ocular concomitant diagnoses in our cohort were eyelid laceration (7.3%) and facial/orbital fracture (7%) (Tables 2 and 3 and Table 4).

## Regression analysis: demographic characteristics

As compared to Medicare patients, Medicaid patients were 1.14 times more likely to have higher ED costs ( 95% CI: 1.01-1.29) and 1.32 times more likely to have extended

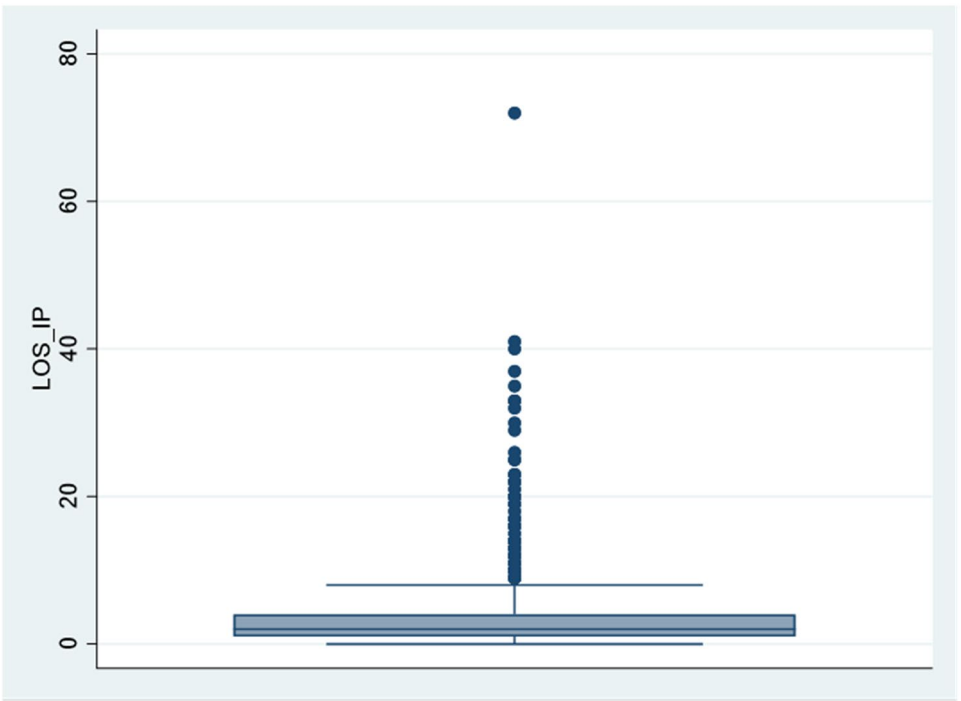


**Figure 2:** Histogram of Length of Stay

**Table 2** Injury Characteristics

| Diagnoses Information | Open Globe Injuries |
|---|---|
| Number | 8404 |
| Number of Diagnoses (Mean ± SD) | 5.87 ± 4.40 |
| Presence of Injury Diagnoses | 8138 (96.8%) |
| Multi Injury | 2813 (33.5%) |
| Injury Type | |
| Cut | 821 (9.8%) |
| Fall | 1566 (18.6%) |
| Firearm | 133 (1.6%) |
| Machinery | 65 (0.8%) |
| Motor Vehicle | 273 (3.2%) |
| Nature | 225 (2.7%) |
| Struck | 3156 (37.6%) |
| Assault | 800 (9.5%) |
| Self Harm | 37 (0.4%) |
| Unintentional | 6459 (76.9%) |

length of stay (95%CI: 1.02-1.71) (Table 5, 6). However, private payers were significantly less likely to have extended length of stay (IRR 0.72, 95%CI [0.56-0.92]). As compared to patients in the 0 to 17 years age group those in 70+ age group were significantly more likely to admitted to the hospital (IRR 1.54, 95%CI [1.25-1.88]) (Table 4). Frail patients were associated with significantly increased likelihood of inpatient admission (IRR 2.22, 95%CI [1.97-2.50]), extended length of stay (IRR 2.15, 95%CI [1.82-2.55]) and higher total combined ED cost (IRR 1.68, 95%CI [1.52-1.85]) (Tables 4, 5, 6).

As compared to non-trauma centers presentation at Level I and Level II trauma center was associated with significantly increased likelihood of inpatient admission (Table 4). As compared to Northeast, patients presenting to EDs in the Midwest and South were significantly associated with likelihood of lower ED costs (Table 5).

### Regression analysis: injury characteristics

While cuts (IRR 1.26, 95%CI [1.05-1.50]) and firearm (IRR 1.28, 95%CI [1.03-1.59]) injuries were associated with non-statistically significantly higher likelihood of inpatient admission, injuries due to machinery (IRR 1.83, 95%CI [1.25-2.68]), motor vehicle (IRR 1.31, 95%CI [1.07-1.59]), and self-harm (IRR 1.69, 95%CI [1.15-2.47]) had significantly higher likelihoods of admission (Table 4). Mechanisms of injury associated with significantly lower likelihood of inpatient admission include nature-related (IRR 0.28, 95%CI [0.15-0.52]), and being struck (IRR 0.67, 95%CI [0.58-0.77]) (Table 4). Falls (IRR 0.77, 95%CI [0.63-0.94]) and being struck (IRR 0.69, 95%CI [0.54-0.88]) were also significantly associated with shorter lengths of stay (Table 6). While motor vehicle incidents (IRR 1.17, 95%CI [1.00-1.36]), and firearm incidents (IRR 1.25, 95%CI [1.04-1.49]) were associated with non-statistically significantly higher ED costs, only self-harm (IRR 1.64, 95%CI [1.22-2.21]) and falls were statistically significantly associated with higher ED costs, (Table 5).

Most ocular concomitant diagnoses were also associated with increased frequency of inpatient admission (Table 4) and higher ED costs (Table 5). Specific concomitant diagnoses linked with significantly higher likelihood of extended length of stay include fracture (IRR 1.60, 95%CI [1.38-1.86]), and endophthalmitis (IRR 2.91, 95%CI [2.07-4.08]) (Tables 6, 7 and 8).

## Discussion

Although OGIs comprise of only a small subset of ocular trauma, presentation in the ED commonly necessitates urgent surgical repair to prevent long term complications such as loss of vision and infection. Using a national database, this study determined the most common demographic and clinical characteristics of OGI patients for 2018 and 2019, as well as the association of demographic and clinical features with various outcome measures such as inpatient admission frequency, length of stay, and total cost. Demographic features such as Medicaid use and frailty were associated with higher ED costs and longer lengths of stay. Presentation at trauma centers was associated with increased inpatient admission rates and worse trauma severity.

The demographic characteristics of the OGI cohort are consistent with the current model described in previous studies, suggesting that previously published data remains valid. Lower income males were the most common

**Table 3** Specific ICD-10-CM Codes Utilized in Open Globe Injuries Cohort

| Diagnosis | ICD-10 Codes |
|---|---|
| Open Globe Injury | S05.2 Ocular laceration and rupture with prolapse or loss of intraocular tissue<br>S05.3 Ocular laceration without prolapse or loss of intraocular tissue<br>S05.4 Penetrating wound of orbit with or without foreign body<br>S05.5 Penetrating wound with foreign body of eyeball<br>S05.6 Penetrating wound without foreign body of eyeball<br>S05.7 Avulsion of eye |

**Table 4** Association of characteristics with hospital inpatient admission frequency

| DEMOGRAPHICS | Incident Risk Ratio |
|---|---|
| Age Categories: | |
| 0-17 | 1 [Reference] |
| 18-29 | 0.84 (0.68, 1.05) |
| 30-39 | 1.08 (0.87, 1.33) |
| 40-49 | 1.10 (0.89, 1.36) |
| 50-59 | 1.17 (0.95, 1.44) |
| 60-69 | 1.09 (0.86, 1.37) |
| 70+ | 1.54 (1.25, 1.88) *** |
| Income Quartile | |
| $1–$45,999 | 1 [Reference] |
| $46,000– $58,999 | 1.13 (1.01, 1.27) * |
| $59,000–$78,999 | 0.99 (0.86, 1.14) |
| $79,000+ | 0.94 (0.81, 1.10) |
| Hospital Trauma Level | |
| Nontrauma Center | 1 [Reference] |
| Level I | 5.20 (4.16, 6.48) *** |
| Level II | 4.52 (3.58, 5.70) *** |
| Level III | 1.12 (0.73, 1.73) |
| Frailty Designation | 2.22 (1.97, 2.50) *** |
| Injury Type | |
| Cut | 1.26 (1.05, 1.50) * |
| Fall | 0.88 (0.76, 1.02) |
| Firearm | 1.28 (1.03, 1.59) * |
| Machinery | 1.83 (1.25, 2.68) *** |
| Motor Vehicle | 1.31 (1.07, 1.59) *** |
| Nature | 0.28 (0.15, 0.52) *** |
| Struck | 0.67 (0.58, 0.77) *** |
| Assault | 1.54 (1.33, 1.79) *** |
| Self Harm | 1.69 (1.15, 2.47) *** |
| Concomitant Diagnoses | |
| Exophthalmos | 0.81 (0.53, 1.24) |
| Ocular hypertension | 1.67 (1.11, 2.51) * |
| Glaucoma | 1.53 (1.19, 1.97) *** |
| Visual loss | 1.91 (1.64, 2.22) *** |
| Corneal transplant status | 1.39 (1.04, 1.85) * |
| Hyphema | 1.38 (1.12, 1.72) *** |
| Traumatic cataract | 1.74 (1.34, 2.27) *** |
| Vitreous hemorrhage | 1.68 (1.38, 2.04) *** |
| Eyelid laceration | 1.64 (1.45, 1.84) *** |
| Contusion of adnexa | 1.53 (1.30, 1.79) *** |
| Endophthalmitis | 3.16 (2.20, 4.54) *** |
| Fracture | 1.99 (1.76, 2.26) *** |
| Orbital hemorrhage | 1.50 (0.97, 2.32) |

*P*-Value Significance: '***' 0.001 '**' 0.01 '*' 0.05

**Table 5** Association of characteristics with ED-associated costs

| DEMOGRAPHICS | Incident Rate Ratio |
|---|---|
| Month | |
| January | 1 [Reference] |
| February | 0.88 (0.72, 1.08) |
| March | 0.97 (0.80, 1.19) |
| April | 0.88 (0.73, 1.07) |
| May | 0.83 (0.70, 0.99) * |
| June | 0.83 (0.69, 1.00) * |
| July | 1.12 (0.92, 1.37) |
| August | 1.02 (0.85, 1.23) |
| September | 0.85 (0.70, 1.03) |
| October | 0.86 (0.72, 1.03) |
| November | 0.98 (0.81, 1.19) |
| December | 0.79 (0.66, 0.96) * |
| Payer | |
| Medicare | 1 [Reference] |
| Medicaid | 1.14 (1.01, 1.29) * |
| Private | 0.94 (0.82, 1.07) |
| Self-pay | 0.81 (0.70, 0.94) *** |
| No charge | 0.57 (0.38, 0.85) *** |
| Other | 0.88 (0.75, 1.03) |
| Income Quartile | |
| $1–$45,999 | 1 [Reference] |
| $46,000– $58,999 | 0.96 (0.87, 1.07) |
| $59,000–$78,999 | 1.03 (0.92, 1.15) |
| $79,000+ | 1.16 (1.02, 1.32) * |
| Frailty Designation | 1.68 (1.52, 1.85) |
| Hospital Region | |
| Northeast | 1 [Reference] |
| Midwest | 0.74 (0.62, 0.88) *** |
| South | 0.77 (0.66, 0.91) *** |
| West | 1.09 (0.92, 1.28) |
| Hospital Trauma Level | |
| Nontrauma Center | 1 [Reference] |
| Level I | 1.31 (1.12, 1.55) *** |
| Level II | 0.96 (0.80, 1.15) |
| Level III | 0.86 (0.63, 1.18) |
| Injury Type | |
| Fall | 0.79 (0.70, 0.88) *** |
| Firearm | 1.25 (1.04, 1.49) * |
| Motor Vehicle | 1.17 (1.00, 1.36) * |
| Self-Harm | 1.64 (1.22, 2.21) *** |
| Concomitant Diagnoses | |
| Visual loss | 0.87 (0.77, 0.98) * |
| Vitreous hemorrhage | 1.11 (0.96, 1.29) |
| Choroidal Detachment | 2.05 (1.19, 3.53) ** |

*P*-Value Significance: '***' 0.001 '**' 0.01 '*' 0.05

population presenting with OGIs to the ED in our study and in past literature, and remained the population associated with the highest frequency of extended length of stay [9]. Our average age of 40 was higher than the average age found in previous studies, which supports an existing trend

**Table 6** Association of characteristics with frequency of extended length of stay in the inpatient population

| DEMOGRAPHICS | Incident Rate Ratio |
|---|---|
| Age Categories: | |
| 0-17 | 1 [Reference] |
| 18-29 | 1.21 (0.80, 1.84) |
| 30-39 | 1.20 (0.80, 1.80) |
| 40-49 | 1.39 (0.92, 2.10) |
| 50-59 | 1.41 (0.95, 2.10) |
| 60-69 | 1.57 (1.02, 2.40) * |
| 70+ | 1.54 (1.01, 2.35) * |
| Female | 1.17 (1.00, 1.37) * |
| Month | |
| January | 1 [Reference] |
| February | 1.07 (0.77, 1.49) |
| March | 1.17 (0.86, 1.60) |
| April | 0.89 (0.63, 1.26) |
| May | 1.12 (0.84, 1.50) |
| June | 0.99 (0.70, 1.40) |
| July | 1.31 (0.98, 1.75) |
| August | 0.91 (0.66, 1.27) |
| September | 1.03 (0.73, 1.45) |
| October | 1.08 (0.78, 1.49) |
| November | 0.98 (0.71, 1.36) |
| December | 0.67 (0.44, 1.01) |
| Payer | |
| Medicare | 1 [Reference] |
| Medicaid | 1.32 (1.02, 1.71) * |
| Private | 0.72 (0.56, 0.92) ** |
| Self-pay | 0.85 (0.61, 1.18) |
| No charge | 0.65 (0.22, 1.96) |
| Other | 0.74 (0.52, 1.03) |
| Hospital Region | |
| Northeast | 1 [Reference] |
| Midwest | 0.71 (0.55, 0.90) *** |
| South | 0.85 (0.67, 1.07) |
| West | 0.79 (0.62, 1.01) |
| Frailty Designation | 2.15 (1.82, 2.55) *** |

*P*-Value Significance: '***' 0.001 '**' 0.01 '*' 0.05

describing increased age of OGI presentation over time [4]. This increase in average age over time could likely be due to increased awareness and protective eyewear use among younger populations, ultimately leading to decreased ocular trauma [10]. However, despite the higher average age in our cohort, the 0-17 age category remained the highest proportion of patients, confirming that younger populations are still the most apt to participate in activities predisposing to ocular trauma and OGIs [5].

The frequencies of various mechanisms of injury found in our study are also consistent with the current model established in the literature. Mir et al. described a concerning trend of an increased frequency of falls over the period of 2006 to 2014, and our study supported that finding, as the frequency of OGIs related to falls increased to 18.6% in 2018-2019 from the 9.6% average in the period of 2006-2014 [4]. The frequency of falls was more common in older patients of our cohort. The rise in proportion of falls as a mechanism of OGIs can be attributed to the growing proportion of elderly patients in the United States, thus highlighting the important need for further fall-related safety measures and training programs [11]. Specifically, in light of this information, primary care physicians may wish to emphasize interventions to minimize the risk of falls in the elderly (i.e., strength training, safety technologies, etc).

The current study also supported the previously-established model associating increased age and inpatient admission frequency [4]. While older adults often have comorbidities which could necessitate more frequent inpatient admissions, the advent of new effective protocols for the management of older adults presenting to the ED during the 2018-2019 time period of the study makes this finding somewhat counterintuitive. For example, the increase in the number of dedicated syncope units in EDs in recent years is designed to address increased rates of falls in the elderly, in the hopes of avoiding inpatient admission [12]. ED Observation Units also help avert some inpatient admissions. Our study further highlights the work that must be done to reduce open globe injury frequency in the elderly population.

In our study, although presentation during warmer spring and summer months constituted the largest proportion of the cohort, the lowest total ED costs occurred during the months of May and June.. This finding builds on previous studies describing increased incidences of ocular trauma during the summer, likely attributed to longer daylight hours leading to a higher prevalence of dangerous outdoor behavior [13]. Our

**Table 7** Distribution of Total Cost, Inpatient Cost, and Length of Stay

| | N | Mean | Standard Deviation | Median | Inter-Quartile Range | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| Total Cost ($) | 8,383 | 18,274.08 | 50,745.05 | 605 | 2,862 | 11 | 395,000 |
| Inpatient Cost ($) | 1,079 | 10,722.54 | 15,463.97 | 7,306 | 6,953 | 525 | 272,111 |
| Length of Stay (days) | 1,079 | 3.354958 | 5.058384 | 2 | 3 | 0 | 72 |

**Table 8** Proportions of Inpatient Admission and Length of Stay

| | Total $N = 8,404$ | |
|---|---|---|
| Patient type | N | Percent |
| Discharged from ED | 6,364 | 75.73 |
| Admitted (Inpatient) | 1,079 | 12.84 |
| Transferred to Other Hospital/Died in ED/Not Admitted/Unknown Destination | 961 | 11.44 |
| | Total $N = 1,079$ | |
| Inpatient Length of Stay | N | Percent |
| Less than 3 days | 673 | 62.37 |
| Extended Stay (3 days or longer) | 406 | 37.63 |

study suggests that although such trauma is more prevalent, the overall severity of the injuries may have decreased over summer months. However, this finding could also be related to external factors such as lack of hospital beds. This study also delineated an interesting new finding of decreased ED costs related to open globe injuries in December. This result may be due to increased injuries related to falls in winter months, [14] with falls being associated in our study with decreased ED costs. On the other hand, this finding could also be related to the winter holidays during this time, with families keeping a somewhat higher threshold to go to the hospital or seek care.

This investigation also provides insight into specific demographics at increased risk of increased consumption of hospital services in the setting of OGIs. As defined by the HFRS, frail patients may experience worse post-surgical outcome measures following total hip and knee arthroplasty [6]. The current study identified that increased frailty is linked with increased inpatient admission, longer stays, and higher total costs in the setting of OGI. Medicaid was another demographic linked with higher frequency of extended length of stay and higher ED costs in both the current cohort and in previous studies examining surgical outcomes in gynecologic oncology [15]. Medicaid patients have been noted to predominantly describe their health as poor and suffer from increased rates of chronic health problems [16]. These findings indicate frailty and Medicaid status as potential predictors of poor outcomes following trauma, as well as accentuate the importance of preventative measures in these at-risk groups.

While various mechanisms of injury were also linked to worse inpatient outcomes, caution must be taken before utilizing these as potential predictors of worse surgical outcomes due to the presence of other potential confounding factors. For example, machinery-related injury was found to be associated with increased likelihood of inpatient admission, while self-harm was associated with higher costs. Increased frequency of inpatient admissions related to machinery could be attributed to the presence of other non-ocular injuries including injury to the extremities, while higher costs seen in self-harm patients could be linked to associated inpatient psychosocial assessment costs and treatment [17].

Location of visit (specifically at trauma centers) was also associated with increased rates of inpatient admission in both our study and in previous studies [4]. Presentation at Level 1 trauma centers was associated with increased total ED costs. Rather than serving as a statement on the level of care at trauma centers, this finding is likely a reflection of the fact that patients presenting to level 1 trauma centers are commonly more severely injured than those presenting to non-trauma centers.

These findings must be contextualized against the limitations of the NEDS database. First, NEDS lacks the capability to track patients across either follow up visits or repeat visits to the ED. Second, diagnoses are labeled using ICD-10 codes, which can vary widely depending on different medical coders and do not capture other clinical characteristics such as severity of trauma or visual acuity. Third, the distribution of ED costs between surgical expenses, hospital resource utilization, and other factors included in the total cost for each patient is not specified in the NEDS database, leading to the inability to exclude month-to-month variability unrelated to the patient's presenting injuries. Finally, the database could be susceptible to errors related to documentation, although the impact of this factor is hopefully mitigated by the large sample size. Furthermore, the multifaceted statistical analysis needed to analyze the data may have possibly led to inflation of some significant results, however the large sample size similarly provides some fidelity to the data. Despite these potential shortfalls, the size of this relatively recent dataset supports the validity of these novel findings. Through identification of features that suggest greater consumption of hospital services, resources could be allocated more effectively to ensure adequate care of vulnerable patients, with a particular emphasis on counseling in the pediatric and geriatric populations. Furthermore, patients could be counseled as to the nature of the most statistically likely post-injury courses.

## Conclusion

This study describes the most common demographic and clinical characteristics of OGIs that present to the ED, as well as the association of these characteristics with outcome measures such as inpatient admission rates, length of stay, and total cost. Further research is needed to explore the trends in order to better identify potential high-risk patients, avoid future injuries, optimize patient care protocols, and improve outcomes following surgical intervention.

**Authors' contribution statements** JKT, SPY, AA, DRP, and EJW were involved in drafting and revising the article, and all authors approved the final version to be published. JKT had full access to all the data in the study and takes responsibility for the integrity and the accuracy of the data.

### Declarations

This article does not contain any studies with human participants or animals performed by any of the authors. No funding was received for this research.

**Ethics approval** This was a study utilizing a publicly available, national database. The IRB of Albany Medical College determined that our study did not need ethical approval. An IRB official waiver of ethical approval was granted from the IRB of Albany Medical College.

**Competing interests** The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

**Disclosures** The authors do not have any financial conflicts of interest to disclose.

## References


1. Iftikhar M, Latif A, Farid UZ, Usmani B, Canner JK, Shah SMA (2019) Changes in the Incidence of Eye Trauma Hospitalizations in the United States From 2001 Through 2014. JAMA Ophthalmol 137:48–56. https://doi.org/10.1001/jamaophthalmol.2018.4685
2. Ozturk T, Cetin Dora G, Ayhan Z, Kaya M, Arikan G, Yaman A (2019) Etiology and Visual Prognosis in Open Globe Injuries: Results of A Tertiary Referral Center in Turkey. Sci Rep 9:17977. https://doi.org/10.1038/s41598-019-54598-w
3. Fong LP (1995) Eye injuries in Victoria, Australia. Med J Aust 162:64–68. https://doi.org/10.5694/j.1326-5377.1995.tb138434.x
4. Mir TA, Canner JK, Zafar S, Srikumaran D, Friedman DS, Woreta FA (2020) Characteristics of Open Globe Injuries in the United States From 2006 to 2014. JAMA Ophthalmol 138:268–275. https://doi.org/10.1001/jamaophthalmol.2019.5823
5. Sahin Atik S, Ugurlu S, Egrilmez ED (2018) Open Globe Injury: Demographic and Clinical Features. J Craniofac Surg 29:628–631. https://doi.org/10.1097/scs.0000000000004156
6. Meyer M, Parik L, Leiß F, Renkawitz T, Grifka J, Weber M (2020) Hospital Frailty Risk Score Predicts Adverse Events in Primary Total Hip and Knee Arthroplasty. J Arthroplasty 35:3498–3504. e3493. https://doi.org/10.1016/j.arth.2020.06.087
7. Gilbert T, Neuburger J, Kraindler J, Keeble E, Smith P, Ariti C, Arora S, Street A, Parker S, Roberts HC, Bardsley M, Conroy S (2018) Development and validation of a Hospital Frailty Risk Score focusing on older people in acute care settings using electronic hospital records: an observational study. Lancet 391:1775–1782. https://doi.org/10.1016/s0140-6736(18)30668-8
8. McAlister FA, Savu A, Ezekowitz JA, Armstrong PW, Kaul P (2020) The hospital frailty risk score in patients with heart failure is strongly associated with outcomes but less so with pharmacotherapy. J Intern Med 287:322–332. https://doi.org/10.1111/joim.13002
9. Hoskin AK, Low R, Sen P, Mishra C, Kamalden TA, Woreta F, Shah M, Pauly M, Rousselot A, Sundar G, Natarajan S, Keay L, Gunasekeran DV, Watson SL, Agrawal R (2021) Epidemiology and outcomes of open globe injuries: the international globe and adnexal trauma epidemiology study (IGATES). Graefes Arch Clin Exp Ophthalmol 259:3485–3499. https://doi.org/10.1007/s00417-021-05266-1
10. Leisy HB, Coritsidis AL (2019) Use of Protective Eyewear During Recreational Activities in Adults of the United States: Analysis from the 2016 National Health Interview Survey. Ophthalmic Epidemiol 26:216–222. https://doi.org/10.1080/09286586.2019.1585884
11. Appeadu MK, Bordoni B (2022) Falls and Fall Prevention In The ElderlyStatPearls. StatPearls Publishing
12. McCabe JJ, Kennelly SP (2015) Acute care of older patients in the emergency department: strategies to improve patient outcomes. Open Access Emerg Med 7:45–54. https://doi.org/10.2147/oaem.S69974
13. Ramirez DA, Porco TC, Lietman TM, Keenan JD (2018) Ocular Injury in United States Emergency Departments: Seasonality and Annual Trends Estimated from a Nationally Representative Dataset. Am J Ophthalmol 191:149–155. https://doi.org/10.1016/j.ajo.2018.04.020
14. Kapadia MK, Koo L, Singh RP, Hatton MP (2003) Seasonal Variation in Open Globe Injuries. Investigative Ophthalmology & Visual Science 44:819–819
15. Ahmad TR, Chen LM, Chapman JS, Chen LL (2019) Medicaid and Medicare payer status are associated with worse surgical outcomes in gynecologic oncology. Gynecol Oncol 155:93–97. https://doi.org/10.1016/j.ygyno.2019.08.013
16. Capp R, Kelley L, Ellis P, Carmona J, Lofton A, Cobbs-Lomax D, D'Onofrio G (2016) Reasons for Frequent Emergency Department Use by Medicaid Enrollees: A Qualitative Study. Acad Emerg Med 23:476–481. https://doi.org/10.1111/acem.12952
17. Tsiachristas A, McDaid D, Casey D, Brand F, Leal J, Park AL, Geulayov G, Hawton K (2017) General hospital costs in England of medical and psychiatric care for patients who self-harm: a retrospective analysis. Lancet Psychiatry 4:759–767. https://doi.org/10.1016/s2215-0366(17)30367-x