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ORIGINAL RESEARCH

Temporal and Seasonal Trends in Pediatric Eye Trauma in California

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Purpose: This study aims to evaluate temporal and seasonal trends in pediatric eye trauma based on emergency department (ED) visits in California.

Design: Retrospective, population-based cohort study.

Methods: Children who presented with ocular trauma to EDs in California between 2016 and 2021 were identified using the California Department of Health Care Access and Information datasets and classified by International Classification of Diseases (ICD) diagnosis codes. Poisson regression was used to model yearly incidence and seasonality was assessed.

Results: Among 15,674,366 ED visits by children in California from 2016 to 2021, 160,730 (1.0%) involved a primary or secondary diagnosis of ocular trauma. The mean age at presentation was 7.6 (SD: 5.6) years. The most common diagnoses were ocular adnexal open wound (51.4%) and superficial injury of the eye/adnexa (23.6%). The overall yearly incidence of eye trauma was 3.0 (95% CI: 3.0–3.0) per 1000 children, peaking in 2017 (3.4) and lowest in 2020 (2.1) and significantly decreased over the study period. Male children and Black and Hispanic/Latino children had the highest incidence of ocular trauma. A significant seasonal pattern was observed, with the highest incidence in May and the lowest in January ($P<0.01$). Geographically, the highest incidences were in the Inland North and Central Valley regions. Over the 6-year period, the percentage of self-pay (uninsured) pediatric patients decreased over time, and public insurance (Medicaid/Title V) remained the most common payor.

Conclusion: Ocular trauma represents a small fraction of ED visits for children in California. The incidence of ocular trauma ED visits decreased over the study period and displayed a seasonal trend. Higher incidence of ocular trauma were observed in male and Black and Hispanic/Latino children.

Keywords: pediatric ocular trauma, emergency department, epidemiology, seasonal trends, health disparities, pediatric ophthalmology

Introduction

Ocular trauma in children is a serious medical and public health concern with implications for both immediate and long-term visual impairment. In the United States in 2014, a child visited the emergency department (ED) for acute ocular injury every 3 minutes, and vision-threatening injuries comprised 1% of these visits.[1] This study also observed an overall decline in ocular injuries from 2006 to 2014, citing possible preventative interventions, but acknowledging that changes in diagnostic codes and coding practices may have artificially affected these trends.[2] However, this remains the most recent longitudinal national analysis of pediatric acute ocular injuries, and it did not examine trends by race or ethnicity. Common causes of pediatric eye injuries include motor vehicle accidents, falls, toy-related incidents, and sports-related injuries; the ocular sequelae of these injuries include abrasions or contusions, conjunctivitis, foreign bodies, chemical burns, lacerations, hemorrhages, thermal burns, and hematomas.[3]

Seasonal trends in pediatric ocular trauma have been described previously, with prevalence peaking in the summer and winter having the lowest prevalence of eye injuries, presumably related to school schedules and outdoor activities.[4–6]

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The COVID-19 pandemic significantly altered children's lifestyles and several studies have demonstrated an overall decrease in ocular trauma during the pandemic, attributed to reduced outdoor activities and increased adherence to safety measures,[7–13] though the proportion of ocular trauma visits relative to total ED visits increased from 16.8% to 23.9% during the pandemic, but only compared 2020 to the aggregated period from 2011 to 2019[11,14] Understanding temporal and seasonal trends in eye trauma may provide insight into the implementation of targeted measures to protect children from ocular injuries and mitigate long-term injury-related visual impairment. Our analysis updates national trends beyond 2014, incorporates race and ethnicity to identify potential disparities, and adds seasonality-specific and post-COVID insights not captured in prior studies. The aim of this study was to evaluate patterns in pediatric ocular trauma in the state of California, using a comprehensive statewide database of all ED visits from 2016 to 2021 to determine the incidence, seasonality, and geographic distribution of pediatric ocular trauma presenting to the ED. We chose to focus on California due to its large, demographically diverse population and the availability of a robust and comprehensive dataset collected by the California Department of Health Care Access and Information (HCAI), which enabled a detailed population-based analysis across multiple years.

Methods

Study Type, Study Population, and Setting

A retrospective population-based cohort study using administrative data was conducted. Children who presented with eye trauma to EDs in California between January 2016 and December 2021 were identified using the California Department of Health Care Access and Information's (HCAI) Emergency Department Dataset (EDD). Visits for eye trauma were identified using International Classification of Diseases 10 (ICD-10) billing codes from either the primary or secondary diagnoses (Supplemental Table 1). Yearly state-level population estimates were obtained from the publicly accessible US Census American Community Survey (ACS) 1-Year Estimates Data Profiles (ACS Table DP05) and used to calculate overall and subgroup incidences.

Classification of Variables

The standardized race/ethnicity group, as defined by the EDD, was used. This variable merges a patient's reported race codes and ethnicity. Patients who selected Hispanic for ethnicity were classified as Hispanic, those who did not select Hispanic and reported multiple race codes were classified as multiracial, and those who did not select Hispanic and reported a single race code were classified by their reported race. Note that prior to 2019, there was no multiracial category recorded. The only modification to the EDD definition was that for 2019–2021, the Asian and Native Hawaiian/Pacific Islander categories were combined into a single category, as they were recorded as one category prior to 2019 (Table 1). When defining the total population's race/ethnicity from the 1-year ACS estimates, the Hispanic or Latino (of any race) variable was used for Hispanic/Latino. The EDD's variable for "preferred language spoken", which reflects the preferred language the patient primarily uses in communicating with those in the healthcare community, was categorized into English, Spanish, other Indo-European languages, Asian and Pacific Island languages, and other languages (Table 1). The ACS's Language Spoken at Home was used to define the total population's preferred language. The EDD-defined payor category was used. A table of abbreviations can be found in Supplemental Table 2. Patients in the self-pay payor category were classified as uninsured. California's 58 counties were categorized into 4 geographic regions: coast, inland north, inland south, and central valley (Supplemental Table 3).

Statistical Methods

Yearly overall incidence estimates were modeled with Poisson regression, using the number of ED visits for pediatric eye trauma as the outcome and the logarithm of the population of interest derived from the 1-year ACS population estimates, as an offset. Incidence rates were also stratified by age, language spoken, race/ethnicity, and gender. Seasonality was assessed with time-series decomposition analysis and several statistical tests of seasonality, including the Kruskal–Wallis, Friedman rank, Welch's ANOVA, and QS tests for seasonality.[15] All analyses were conducted in R (Version 4.3.0) and figures were generated with R package ggplot2.

Table 1 Patient Demographics for Pediatric ED Visits for Ocular Trauma

Characteristics	n=160,730	
Sex		
Male	104,331	64.9%
Female	56,382	35.1%
Unknown	17	<0.1%
Age (years)		
0–5	74,706	46.5%
6–11	40,583	25.2%
12–18	45,441	28.3%
Self-Reported Race/Ethnicity		
American Indian / Alaska Native	563	0.4%
Asian / Pacific Islander	11,046	6.9%
Black	12,679	7.9%
Hispanic	75,685	47.1%
Multiracial	994	0.6%
Other	9351	5.8%
Unknown	2257	1.4%
White	48,150	30.0%
Patient Primary Language Spoken		
Asian and Pacific Islander Languages	948	0.6%
English	139,627	86.9%
Other Indo-European Languages	483	0.3%
Other Languages	641	0.4%
Spanish	19,031	11.8%
Insured vs Uninsured		
Insured	151,647	94.3%
Uninsured	9083	5.7%
Insurance by subcategory		
Disability/WC	650	0.4%
MC/TV	84,676	52.7%
Medicare A/B and Medicare Risk HMO	1921	1.2%
Other	220	0.1%
Other Federal and Non-federal programs	1164	0.7%
PPO/POS/EPO/HMO/BC/BS/Auto/Commercial	60,876	37.9%
Self-pay/uninsured	9083	5.7%
Tricare/VA	2140	1.3%

Abbreviations: PPO, Preferred Provider Organization; POS, Point of Service; EPO, Exclusive Provider Organization; HMO, Health Maintenance Organization; BC, Blue Cross; BS, Blue Shield; WC, Workers' Compensation; MC, Medicaid (Medi-Cal); TV, Title V; VA, Veteran Affairs Plan.

Results

Of the 71,966,227 total ED visits in the state of California over the 6-year study period (2016–2021), 15,674,366 (21.8%) were for children ≤18 years. Of these, 160,730 (1.0%) had a primary or secondary diagnosis of eye trauma. There was a male predominance (64.9% male), and the mean age at the time of presentation was 7.6 years (standard deviation 5.6 years; median 6.0 years; IQR =3.0–13.0 years). Most visits were for children aged 0–5 years (46.5% of all pediatric eye trauma visits), followed by 12–18 years (28.3%) and 6–11 years (25.2%). When expressed as an incidence per 100,000 people enumerated on the Census data was used to estimate annual incidence rate (Figure 1). The highest incidence of ocular trauma ED visits was seen in 1-year-olds and the incidences steadily decreased throughout childhood before rising again at age 13 (Figure 1). The most common self-reported race/ethnicity was Hispanic (47.1%), followed by White (30.0%), and the most common primary language spoken was English (86.9%). A majority of patients were insured

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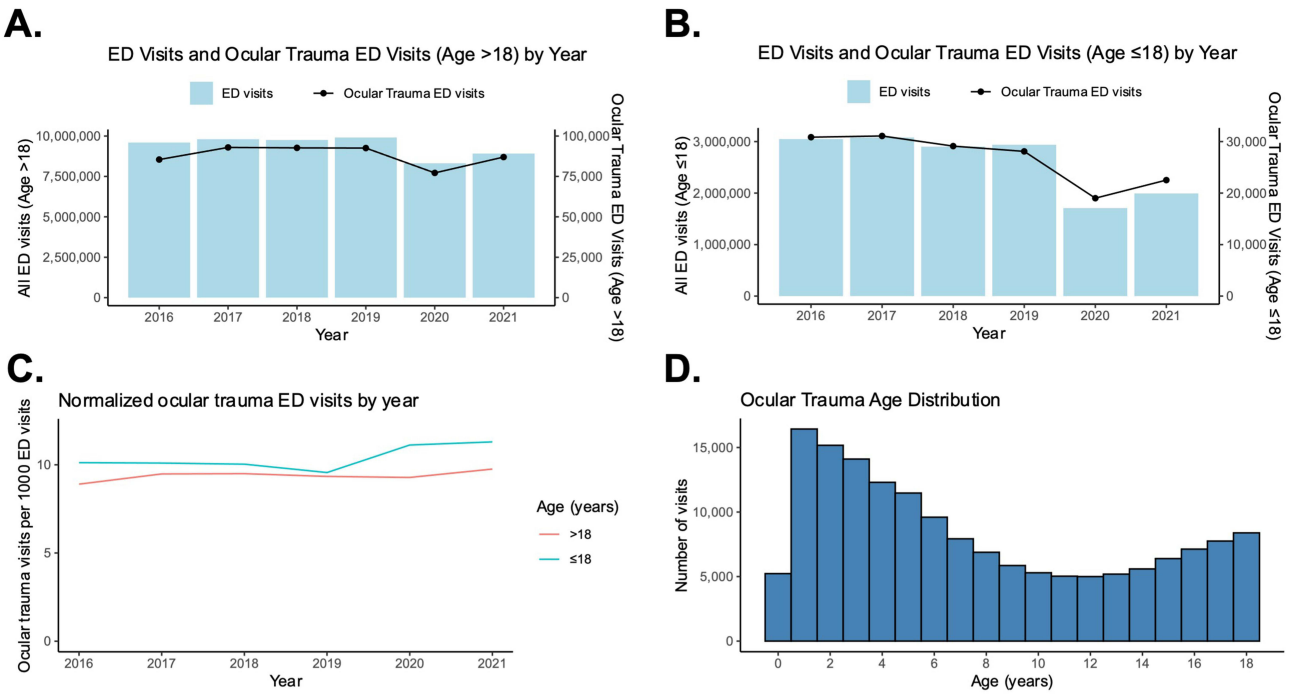

Figure 1 Ocular trauma-related ED visits between 2012 and 2021. (**A**) Number of all ED visits and ocular trauma ED visits by year for adults >18 years; (**B**) number of all ED visits and ocular trauma ED visits by year for children ≤18 years; (**C**) normalized ratio of ocular trauma ED visits to total ED visits by year; (**D**) number of visits by age.

(94.3%) and the most common insurance type was Medicaid (52.7%; Table 1). The most common diagnosis was an ocular adnexal open wound, accounting for 51.4% of all visits, followed by superficial injury of eye/adnexa (23.6%), contusion of eye and adnexa (13.4%), and extraocular foreign body (4.6%) (Table 2).

The proportion of eye trauma-related visits increased over time compared to all ED visits and this trend in children mirrored that seen in adults over the same time period (Figure 1). The overall incidence of ED visits for eye trauma was 3.0 [95% CI: 3.0–3.0] per 1000 children per year and was highest in 2017 (3.4) and lowest in 2020 (2.1; Figure 2). There was a significant decrease in the monthly incidence during the study period (P<0.001; Mann-Kendall). Male children had a 1.9-fold higher incidence than female children (3.9 [3.9–3.9] and 2.1 [2.1–2.1] visits per 1000 children, respectively). Incidence was highest in Black and Hispanic/Latino children (4.3 [4.3–4.4] and 3.6 [3.6–3.6]) when compared to American Indian/Native American (3.1 [2.9–3.4]), White (2.5 [2.4–2.5]), and Asian/Pacific Islander (1.4 [1.4–1.4] visits per 1000 children, Figure 2). Patients whose principal language was English had the highest incidence of visits (4.7

Table 2 Diagnostic Categories for Children < 18 Years Seen in California Emergency Departments for Eye Trauma During the Study Period (2016–2021). Values Represent the Number of Encounters and Proportion of Total

Injury Category	n=160,730
Burn of eye and adnexa	1961 (1.2%)
Contusion of eye and adnexa	21,595 (13.4%)
Extraocular foreign body	7407 (4.6%)
Ocular adnexal open wound	82,688 (51.4%)
Open wounds in the eyeball	7408 (4.6%)
Orbital fracture	1729 (1.1%)
Other	16 (0.0%)
Superficial injury of eye/adnexa	37,925 (23.6%)

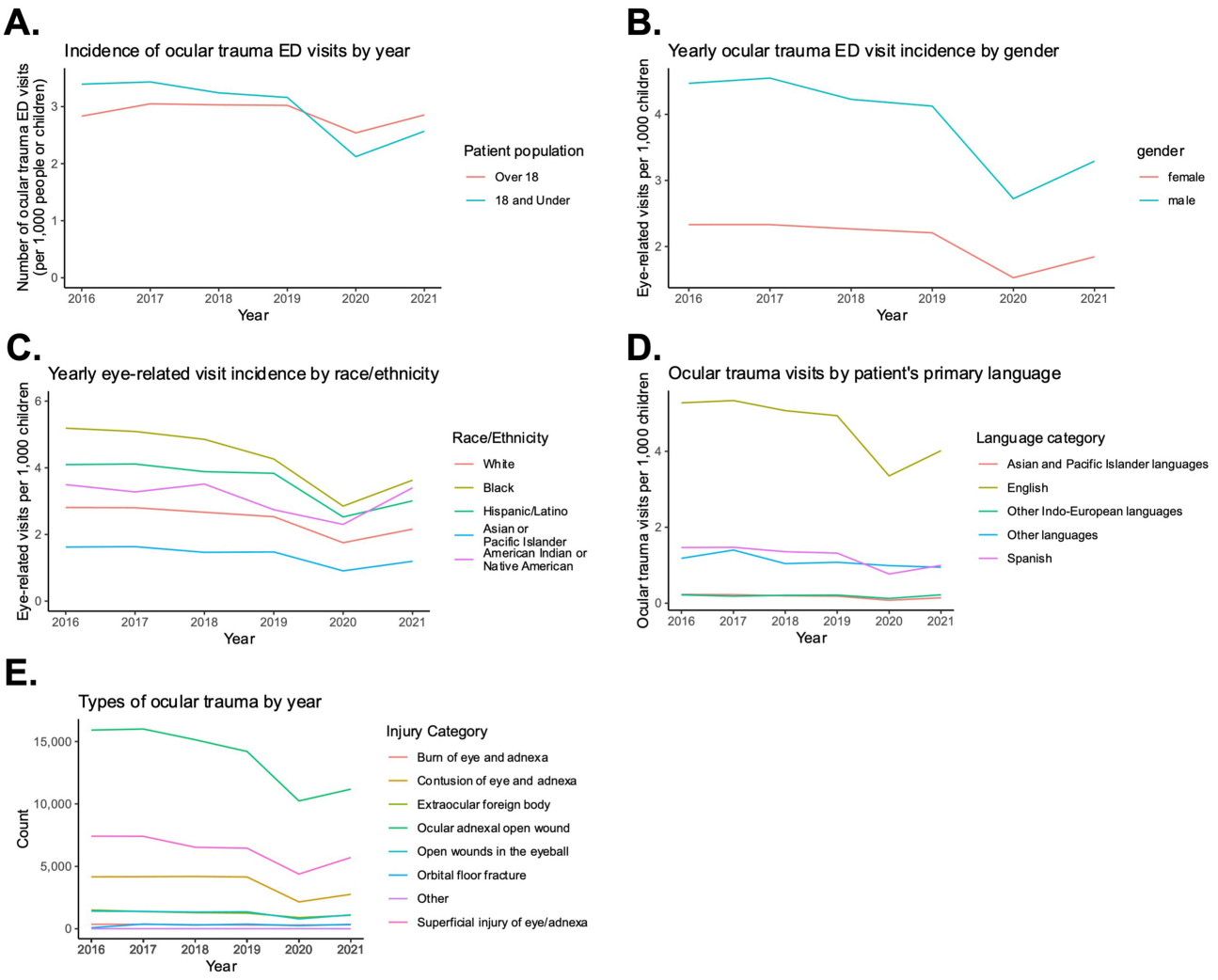

Figure 2 Yearly incidence (ED visits per 1000 individuals) in ocular trauma-related ED visits. (**A**) Adults >18 years and children ≤18 years; (**B**) children stratified by gender; (**C**) children stratified by self-reported race/ethnicity; (**D**) children stratified by primary language; (**E**) children stratified by type of ocular trauma.

[4.6–4.7]), followed by Spanish-speaking patients (1.2 [1.2–1.3] visits per 1000 children). The proportion of each eye trauma diagnostic code per year remained stable over the study period, with no significant differences observed in the distribution of codes by year (Figure 2). There was a statistically significant seasonal pattern in pediatric eye trauma visits (All P<0.01; Ollech and Webel's combined seasonality test). The highest incidence of pediatric eye trauma was in May (2.8 visits per 1000 children) and the lowest in January (2.2 visits per 1000 children; Figure 3). Seasonality was observed in both male and female patients and was most notable among the 0–5 age group (Figure 3).

A geographic analysis showed that the highest monthly incidences of pediatric eye trauma were in the Inland North and Central Valley regions (2.9 [2.8–3.0] and 2.6 [2.5–2.6] visits per 10,000 children) and lowest monthly incidences were in the Coast and Inland South regions (2.3 [2.3–2.3] and 2.4 [2.4–2.4] visits per 10,000 children; Figure 4).

Over the 6-year period, the percentage of self-pay (uninsured) pediatric patients decreased significantly over time (January 2016-December 2021: P=0.009 using Mann-Kendall; Figure 5). Out of 160,730 total visits for ocular trauma, the most common type of insurance or payor was public (Medicaid/Title V) (84,676 visits; 52,7%) followed by private insurance (60,876 visits; 37.9%), uninsured (9083 visits; 5.7%), and Tri-care/Veteran Affairs insurance (2140 visits; 1.3%).

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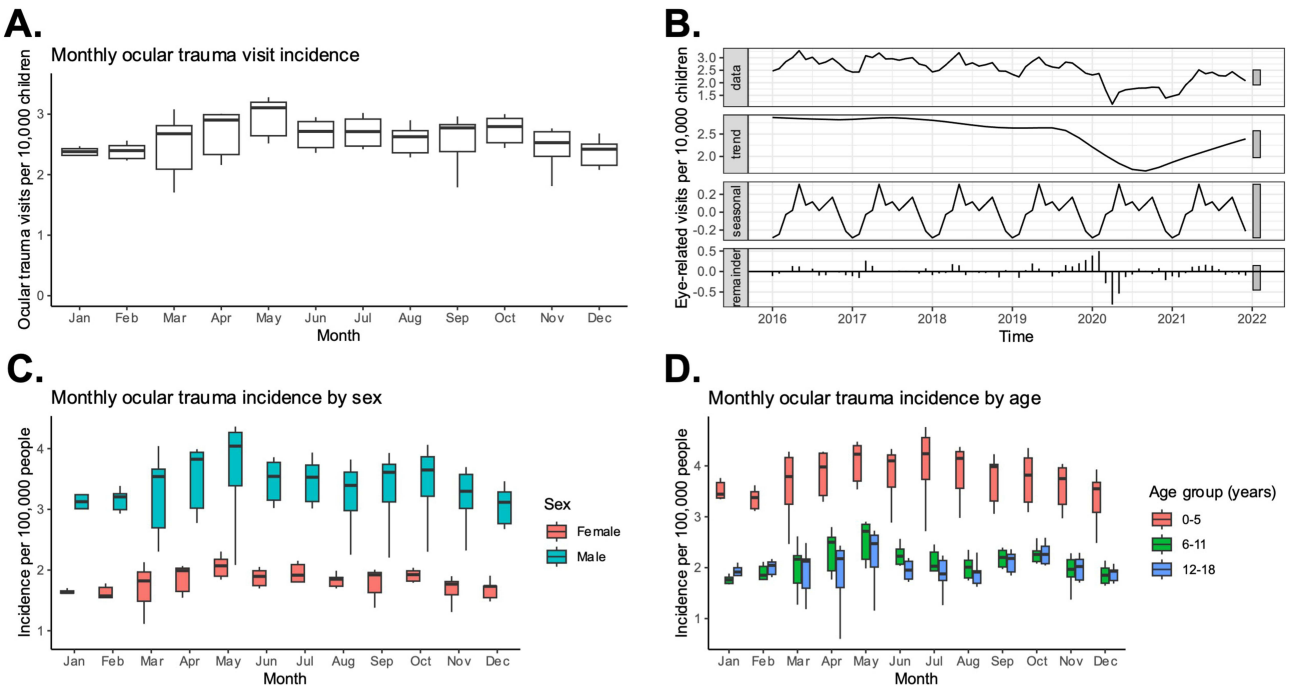

Figure 3 Monthly trends in ocular trauma-related ED visits among children ≤18 years. (**A**) Incidence of ocular trauma ED visits by month per 10,000 children; (**B**) seasonality of ocular trauma ED visits; (**C**) monthly incidence of ocular trauma ED visits per 10,000 children by sex; (**D**) monthly incidence of ocular trauma ED visits per 10,000 children by age.

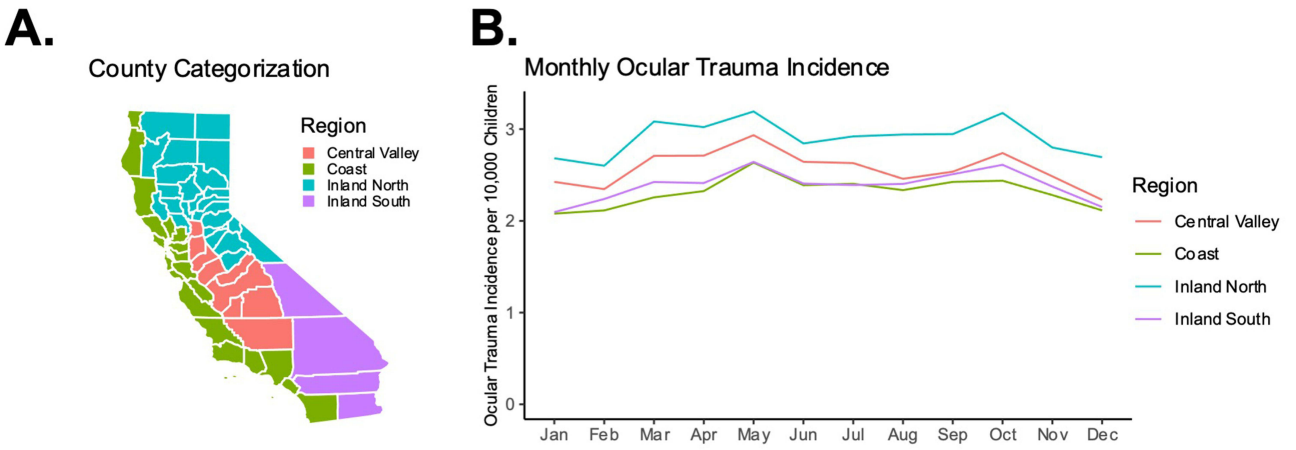

Figure 4 Ocular trauma-related ED visits by geographic regions. (**A**) California county categorization into four geographic regions; (**B**) monthly ocular trauma incidence across regions per 10,000 children.

Discussion

Over the 6-year study period (2016–2021), 1.0% of pediatric ED visits in California involved eye trauma. While the overall incidence of pediatric ocular trauma ED visits decreased significantly over the study period, the proportion of pediatric ocular trauma relative to all pediatric ED visits increased, potentially reflecting different ED usage patterns specific to ocular complaints during the COVID-19 pandemic. The observed decline in incidence may be partly attributable to the COVID-19 pandemic, during which overall emergency department visits, including pediatric ocular trauma, decreased across all demographics. However, this downward trend also aligns with earlier nationwide studies from 2006–2014[1] and 2010–2019[16] which documented a steady decline in ocular trauma incidence over the past two decades, even prior to the COVID-19 pandemic. The most common

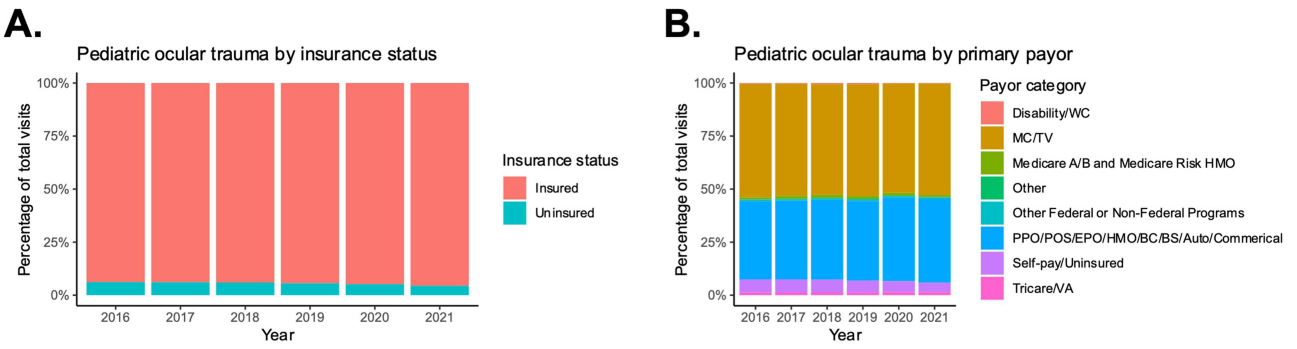

Figure 5 Payor mix over time. (**A**) Percentage of visits by insurance status; (**B**) percentage of visits by payor category. Patients with payer category "Self-pay/Uninsured" were designated as insurance status uninsured. Patients with all other payer categories were designated as insurance status insured.

diagnoses were ocular adnexal open wounds, superficial injuries of the eye/adnexa, and contusions. Visit incidence followed seasonal peaks in spring and fall (particularly October and May), with a nadir in the winter.

The male predominance (64.9%) noted in this study is consistent with national and worldwide data on pediatric ocular trauma.[1,3,4,17] The most common age group presenting with ocular trauma was pre-school aged children (0–5 years). Our finding of a roughly bimodal distribution of pediatric ocular trauma—with the highest incidence in children aged 1–4 years and a secondary peak in adolescents aged 15–18 years—is consistent with prior US population-based studies. Children from birth to age 4 have been shown to have the highest risk of ocular trauma,[1] likely due to caregiver inattention and domestic hazards such as household cleaners or pets. Additionally, two epidemiologic studies conducted from 2001–2007 and 2010–2019 identified adolescents aged 15–17[18] and 11–20 years[16] as having the highest or second-highest rates of eye injuries, often related to sports, recreational activities, or non-powder firearms.

Seasonal trends in pediatric ocular trauma have been described. A 16-year retrospective study in Split, Croatia found that pediatric eye injuries requiring hospitalization were most prevalent in the summer, followed by spring, winter, and autumn.[4] A 2023 study in eastern India also found summer to be the most common season for childhood ocular trauma.[5] In the United States, a retrospective cross-sectional study using data from the National Emergency Department Sample noted eye trauma visits were highest in July and lowest in February.[6] In our study, we found that May and October had the highest incidence of pediatric eye trauma emergency room visits in California, regardless of geographic region. This pattern aligns with previously reported seasonal trends in pediatric trauma, which are thought to reflect increased participation in outdoor and recreational activities. For example, the incidence of musculoskeletal extremity injuries in children nearly double in autumn, summer and spring when compared to winter,[19] and the incidence of pediatric head injuries also peak during the fall months.[20]

Over the 6-year study period, the percentage of uninsured children declined, likely reflecting broader policy changes such as implementation of the Affordable Care Act. Public insurance (Medicaid/Title V) remained the most common type of health insurance coverage in our cohort, insuring over half of all patients and aligns with national estimates that approximately 50% of all US children were covered by Medicaid and/or the Children's Health Insurance Program (CHIP) as of 2022.[21] These findings are consistent with broader trends in California, where the number of uninsured nonelderly Californians decreased from 7.3% in 2016 to 7.0% in 2020.[17] This represents continued progress since the rollout of ACA, which reduced the uninsured rate in California from 16% in 2013 to 11% in 2014.[18] Nationwide, the uninsured rate for children declined from 12.1% in 2000 to 5.3% in 2014.[22] Together, these data demonstrate the critical role of public insurance programs in ensuring access to care for pediatric populations.

This study has several limitations. Diagnostic coding was performed by ED physicians, which may result in misclassification. Also, while California is the most populous state, the findings may not be generalizable to other regions or contexts (such as eye trauma evaluated by primary care physicians or ophthalmologists).

In summary, we comprehensively described the epidemiology of all pediatric ocular trauma visits in California over a 6-year period. We find that ocular trauma represents a small fraction of ED visits for children in California, and that the overall incidence of childhood ocular trauma presenting to the ED is decreasing over time with a significant seasonal

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trend. We also describe health disparities, finding an increased incidence of pediatric ocular trauma in Black and Hispanic/Latino children. These findings highlight the need for further epidemiologic studies of pediatric ocular trauma, including linking ED data with outpatient records, examining longer timeframes, and expanding analyses beyond California to other regions and national datasets to better characterize the incidence trends and disparities we observed. Following demographic, temporal, and seasonal trends in pediatric eye trauma may allow targeted public health interventions during high-incidence seasons or high-risk communities to decrease ocular injury in children.

Ethical Considerations

The study adhered to the principles of the Helsinki Declaration and received approval from the UCSF Human Research Protection Program Institutional Review Board (IRB) (UCSF IRB #: 23-38329) (Reference #: 366547). This study data was requested from the CA dept of health care access and information which provided a deidentified dataset and therefore is not considered human subjects research and does not require informed consent. Research protocols must be approved by the Committee for the Protection of Human Subjects (CPHS). The CPHS protocol must be renewed annually and kept current while the researcher has the data. CPHS is the state Internal Review Board for the California Health and Human Services Agency.

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Disclosure

The authors report no conflicts of interest in this work.

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