Pediatric craniocerebral gunshot injuries: A National Trauma Database study

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BACKGROUND: We aimed to determine the outcomes and prognostic factors in pediatric craniocerebral gunshot injury (CGI) patients. Pediatric patients may have significantly different physiology, neuroplasticity, and clinical outcomes in CGI than adults. There is limited literature on this topic, mainly case reports and small case series.

METHODS: We queried the National Trauma Data Bank for all pediatric CGI between 2014 and 2017. Patients were identified using *International Classification of Diseases, Ninth Revision*, codes. Demographic, emergency department, and clinical data were analyzed. Subgroup analysis was attempted for groups with Glasgow Coma Scale (GCS) scores of 9 to 15 and ages 0 to 8 years.

RESULTS: In a 3-year period, there were 209 pediatric patients (aged 0–18 years) presenting to American hospitals with signs of life. The overall mortality rate was 53.11%. A linear relationship was demonstrated showing a mortality rate of 79% by initial GCS in GCS score of 3, 56% in GCS scores of 4 to 8, 22% in GCS scores of 9 to 12, and 5% in GCS scores of 13 to 15. The youngest patients, aged 0 to 8 years, had dramatically better initial GCS and subsequently lower mortality rates. Regression analysis showed mortality benefit in the total population for intracranial pressure monitoring (odds ratio, 0.267) and craniotomy (odds ratio, 0.232).

CONCLUSION: This study uses the National Trauma Data Bank to quantify the prevalence of pediatric intracranial gunshot wounds, with the goal to determine risk factors for prognosis in this patient population. Significant effects on mortality for invasive interventions including intracranial pressure monitoring and craniotomy for all patients suggest low threshold for use of these procedures if there is any clinical concern. The presence of a 79% mortality rate in patients with GCS score of 3 on presentation suggests that as long as there is not a declared neurologic death, intracranial pressure monitoring and treatment measures including craniotomy should be considered by the consulting clinician. (*J Trauma Acute Care Surg.* 2022;92: 428–435. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic and epidemiological, level III.

KEY WORDS: Neurotrauma; gunshot wound; craniocerebral gunshot injury; intracranial; National Trauma Database.

The incidence of pediatric craniocerebral gunshot injury (CGI) is increasing, with firearm-related injuries remaining the third leading cause of death in children aged 1 to 18 years in the United States. This group of deaths surpasses the number of deaths from malignant neoplasms, congenital anomalies, heart disease, influenza and pneumonia, chronic lower respiratory disease, cerebrovascular causes, or septicemia in this age group.[1] Firearm-related injuries remain second to only motor vehicle collisions for injury-related deaths in children.[1] In further stratifying pediatric age groups, suicide by firearm is the third most common cause of death for children aged 10 to 19 years, homicide by firearm is the fourth most common cause of death for ages 5 to 14 years and second for ages 15 to 19 years.[2] In 2018, the mortality incidence for pediatric gunshot wounds was 3.22 deaths per 100,000 population, increased from 2.50 deaths per 100,000 population in 2010.[1] The highest mortality for gunshot injuries exists in injuries to the head and neck,[2,3] with up to 40% of firearm deaths related to intracranial injury.[3]

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These statistics provide sobering confirmation that CGI is an important injury pattern that requires improved understanding for trauma care providers.

The pathophysiology of pediatric brain injury may differ from that of adult patients. The existence of a larger head to body size ratio, pliability of bone, unfused sutures, thinner skull, weak ligaments, and underdeveloped musculature has been implicated in worse prognosis in both deceleration injuries and blunt craniocerebral trauma in the pediatric population.[4,5] If patients achieve survivorship, children may develop significant clinical improvements, which could be related to neuroplasticity and ongoing development.[6–9] Evidence-based management currently focuses on first principles of trauma management and prevention of secondary brain injury.[10,11] Notably, a 2016 update in pediatric neurotrauma notes significant heterogeneity in age and type of injury prevents appropriately powered studies, therefore limiting evidence-based recommendations.[12]

Guidelines state that pediatric head trauma should be managed through stabilization and supportive resuscitation per standard trauma protocols with computed tomography scan in all moderate and severe trauma of any etiology and in all intracranial gunshot wounds.[13]

A recent systematic review and meta-analysis sought to analyze literature on children younger than 18 years presenting to hospital with isolated CGI in terms of mortality, in an effort to determine prognostic risk factors. In survivors, it was determined that only 9.4% have a poor outcome with a Glasgow Outcome Scale score of 2 or 3, suggesting that long-term clinical improvement is much higher than one would expect with this type of injury.[9] In terms of prognostic factors, Duda et al.[9] found that fixed and dilated pupils and a Glasgow Coma Scale (GCS) score of 3 were consistently but not always associated with death in all studies. Overall mortality in this study was 44.8%, limited to penetrating CGI, in contrast with previous studies by Hofbauer et al.,[14] reporting an overall mortality of 87% in adult patients with penetrating CGI. Duda et al.[9] noted a potential selection bias, with small pediatric populations reported and perhaps a survival bias of fragile pediatric patients; however, this is suggestive of a prognostic difference between adult and pediatric patients that warrants further investigation. This difference suggests that a different approach to these clinical entities may be warranted. Duda et al.[9] also determined that the overall quality of recent literature on this topic is evolving and included eight studies in total, with only three recent retrospective studies. They found a reporting bias toward older teenagers, limiting analysis, as insufficient data were available for children younger than 13 years. The overall finding of this comprehensive review was an identified need for large studies considering prognostic risks in pediatric patients, with a specific focus on younger children.

This retrospective review sought primarily to determine prognostic risk factors and epidemiological factors for mortality in individuals younger than 18 years presenting to hospitals in the United States with intracranial gunshot wounds, with a secondary objective to identify modifiable injuries and age-related outcomes.

PATIENTS AND METHODS

The National Trauma Data Bank (NTDB) was queried for all cases of pediatric trauma between 2014 and 2017 in patients 18 years or younger. Craniocerebral gunshot injury patients were identified by *International Classification of Disease, Ninth Revision*, codes 800 to 804 for skull fracture and 851 to 854 for intracranial injury. *International Classification of Diseases, Ninth Revision*, codes for gunshot wound as mechanism of injury were also queried (E922, E922.3, E922.8, E922.9, E955, E955.4,

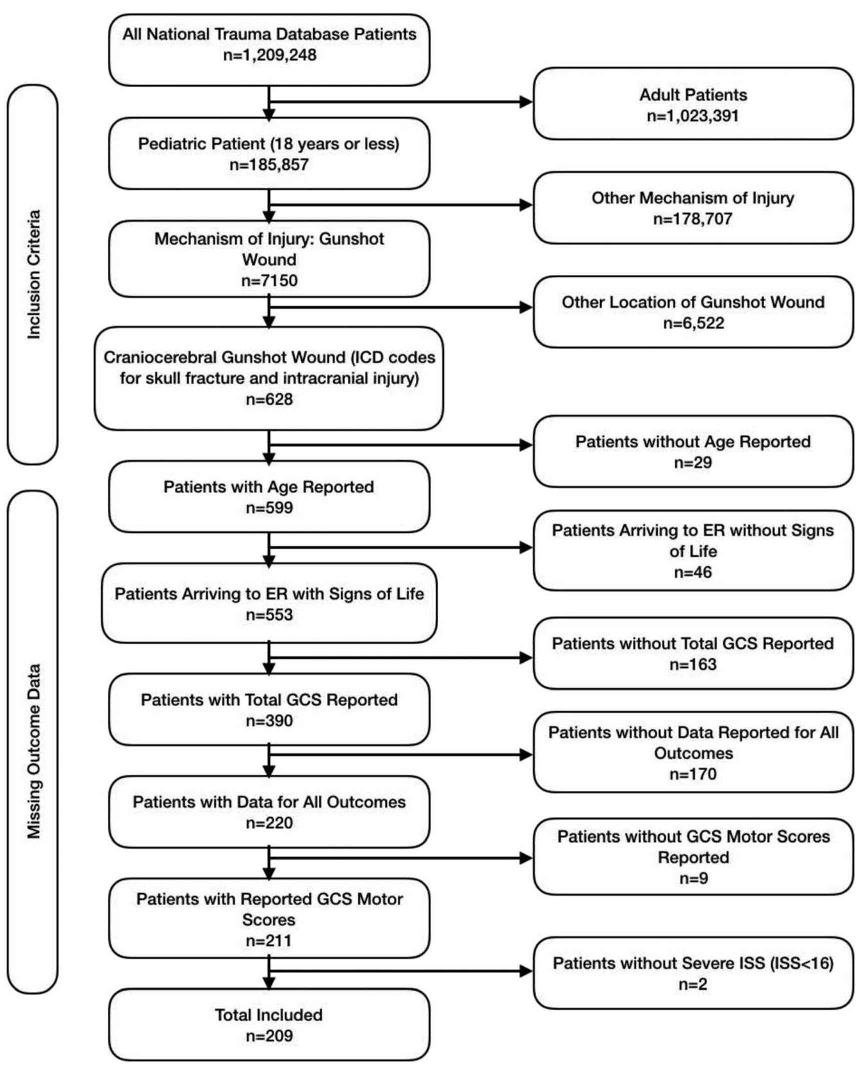

Figure 1. Study population flow chart.

E965, E965.4). Cases were restricted to those with an Injury Severity Score (ISS) of greater than 16 to ensure data quality; severe head injury alone produces an ISS of 16; as such, it is reasonable to conclude that any CGI would meet this criteria, and therefore, lower scores were excluded. Records with missing information were excluded.

Demographic variables extracted included age, sex, payment type, transport type, interfacility transfer status, emergency medical services response time, presenting location, and ethnicity. Age was separated by years into categories of 0 to 2, 3 to 8, 9 to 12, 13 to 15, and 16 to 18. Payment type was separated into categories of government insurance (Medicaid, Medicare, other government), private insurance (Blue Cross/Blue Shield, private/commercial insurance), and other (self pay, not known/recorded, other). Clinical variables extracted included initial GCS, blood pressure, shock on presentation, ISS, pulse oximetry, drug use, alcohol use, mortality, use of intracranial pressure (ICP) monitor, use of craniotomy, emergency department disposition, length of stay, hospital discharge disposition, and complications reported. Glasgow Coma Scale was separated by severity into categories of 3, 4 to 8, 9 to 12, and 13 to 15, based on Advanced Trauma Life Support classification into mild,[13–15] moderate,[9–12] and severe[3–8] traumatic brain injury.[15] A GCS score of 3 was considered a separate category, as a previous systematic review and meta-analysis identified GCS score of 3 as an independent risk factor for mortality.[9]

Statistical Analysis Software (SAS version 9.4; SAS Institute Inc, Cary, NC) was used for all statistical analyses. Univariate analysis was completed for nominal and categorical variables, χ^2 testing and ORs were determined for these variables, including subgroup analysis of a potential "modifiable injury group."

Logistic regression was performed for mortality by age, GCS, race, sex, insurance, and procedures (ICP monitor, craniotomy). Statistical significance for all analyses was set at a p value of 0.05.

RESULTS

Over the 4-year period, NTDB included 209 admissions to American hospitals for CGI, arriving with signs of life and ISS of greater than 16, among patients aged 0 to 18 years (Fig. 1). The overall mortality for these patients was 53.11%. The majority of patients were aged 16 to 18 years, and 85.7% were male. A total of 45.5% of patients were listed as government insurance, 44.98% were listed as private insurance, and the remaining 9.57% were listed as other (Fig. 2).

On presentation, shock was present in only 28.2% of patients, and the majority (51.7%) of patients presented with an oxygen saturation of greater than 92%. In terms of neurologic condition on presentation, total GCS revealed an asymmetrical bimodal distribution, with 48.3% of patients presenting with a score of 3 and 15.3% with a score of 15 (Fig. 3).

A small number of patients in this study did have confirmed drugs or alcohol in their system on presentation. Alcohol was detected in 18.9% of tested patients, with 40% of those patients having levels beyond the legal limit. Drug testing was divided into illegal drugs (40.7% of tested patients) and prescription drugs (16.3% of tested patients).

The most common emergency medical services dispatch location was home (57.4%), followed by street (20.6%). The majority of patients were taken from the scene via ground ambulance (71.8%) and were transferred to their treating facility without requiring interfacility transfer (87.1%). Emergency department discharge disposition was most frequently recorded as intensive care unit (77.0%), with 18.2% transferred directly from the emergency department to the operating room.

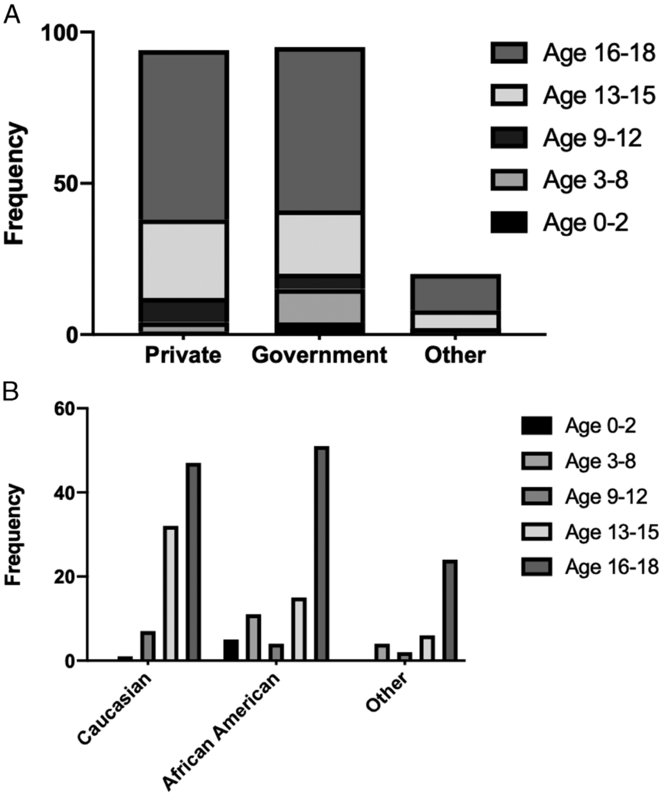

Figure 2. Demographic characteristics of initial presentation with grouping by age categories. (*A*) Insurance by age categories. (*B*) Race by age categories.

Interventions performed included ICP monitor in 25.8% of patients and craniotomy in 26.3%. "Other" procedures were reported in 73.7% of patients. No description of the types of procedures considered in this group was provided.

Infectious complications included 1 incidence of surgical site infection, 13 cases of pneumonia, and 5 urinary tract infections. There were 12 cardiac arrests, 2 unplanned intubations, 1 unplanned return to intensive care unit, and 1 unplanned return to the operating room. There were two incidences of deep vein thrombosis and one decubitus ulcer. There were a number of undefined complications, which represented the most common category, with 166 occurrences.

Presenting GCS score of 3 was found in 48%, GCS scores of 4 to 8 in 21%, GCS scores of 9 to 12 in 11%, and GCS scores of 13 to 15 in 20% (Fig. 3). Presenting GCS was dramatically different in patients aged 0 to 8 years, with far fewer patients presenting as GCS scores of 3 to 8 in this age group (Fig. 2). In patients aged 0 to 2 years, 40% presented with GCS scores of 13 to 15 and an additional 40% with GCS scores of 9 to 12. The patients aged 3 to 8 years offered an intermediate presentation with 19% at GCS scores of 13 to 15 and 19% at GCS scores of 9 to 12. Patients older than 12 years presented in accordance with the overall results.

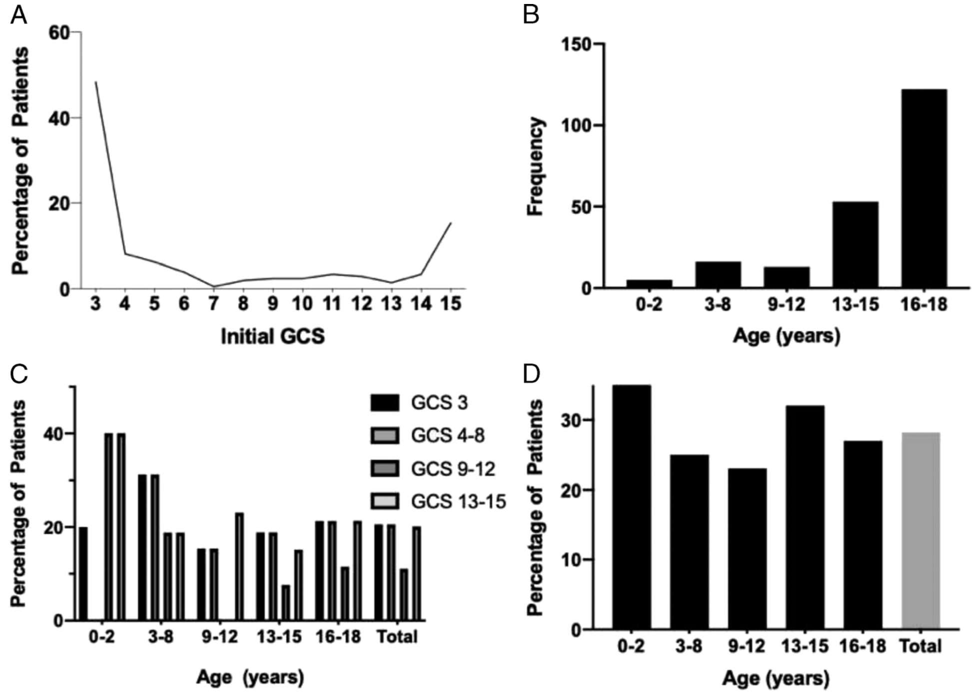

Figure 3. Clinical characteristics of initial presentation. (*A*) Percentage of patients by initial GCS. (*B*) Frequency of CGIs by age. (*C*) Percentage of each age group presenting by GCS group. (*D*) Percentage of patients in each age group presenting with shock.

On analysis of mortality, there was a dramatic difference noted for the youngest patients. Mortality was 20% in ages 0 to 2 years, 31% in ages 3 to 8 years, 69% in ages 9 to 12 years, 64% in ages 13 to 15 years, and 51% in ages 16 to 18 years (Fig. 4). Mortality correlated with GCS in a linear fashion. Mortality was 79.2% in the GCS score of 3 group, 55.81% in the GCS scores of 4 to 8 group, 21.7% in the GCS scores of 9 to 12 group, and 4.8% in the GCS scores of 13 to 15 group (Fig. 4).

The average length of hospital stay was 8.7 days (SD, 11.8 days), with the majority (61.2%) of patients discharged from hospital after 1 day, with the longest reported hospital stay for one patient at 71 days. From hospital, 26.5% of patients were transferred to rehabilitation, while 45.9% of patients were able to return home with normal functional status (Fig. 5).

A subgroup analysis of patients discharged after 1 day (n = 60) revealed that 95% of these patients had died after 1 day. The three remaining patients (two public insurance, one private insurance) were discharged to another hospital.

Summary of patient characteristics is provided in Table 1.

Logistic Regression Analyses

Regression analyses were performed with the following covariates: age, presence of shock, ICP monitor insertion, craniotomy, sex, ethnicity (African American, White, other), and insurance status (private, government, other) to determine effect on mortality (Table 2).

Overall regression analysis was significant with benefit for both better clinical presentation and interventions. Survivorship was significantly better in patients presenting with GCS scores of 9 to 13 compared with a GCS score of 3 (odds ratio [OR], 0.131; confidence interval [CI], 0.033–0.524). Similarly, GCS scores of 14 to 15 were dramatically better than a GCS score of 3 (OR, 0.007; CI, 0.001–0.038). There was a significant survivorship benefit to the use of ICP monitors (OR, 0.267; CI, 0.082–0.864) and craniotomy (OR, 0.232; CI, 0.068–0.796) (Table 2). There was no significant difference for presenting with or without shock (OR, 1.061; CI, 0.426–2.639) (Table 2). Odds of death were lower in patients with government insurance than patients with private insurance (OR, 0.33; CI, 0.134–0.812).

Because of the lack of significance on initial regression analysis for comparisons between ages, a subgroup analysis of the patients aged 0 to 8 years was attempted. This group was selected, as the mortality rate was lower than older patients. We sought to determine any prognostic factors specific to this group to explain this difference. Unfortunately, because of the relatively lower number of patients in this age category, no statistically significant results could be obtained.

Notably, there was no statistically significant difference in mortality on regression analysis for GCS scores of less than 4 to 8, compared with our GCS score of 3 group (OR, 0.458; CI, 0.176–1.195) (Table 2); therefore, a modifiable injury subgroup was defined as a GCS score of 9 or above on presentation (in keeping with mild to moderate severity traumatic brain injury as per Advanced Trauma Life Support guidelines[15]) with an ISS of 16 or greater. Within this group, there were 65 patients. Again, the majority (61.5%) were ages 16 to 18 years, and 80% were male. African American patients represented 53.9% of this group. The majority were government insurance, with 49.2% receiving Medicaid specifically (53.8% from all government sources). Only 8 of these patients presented in shock (12.31%), 21 underwent placement of ICP monitor (32.31%), and 23 underwent craniotomy (35.4%). Among these, the average length of hospital stay was 9.9 days (SD, 7.33 days), with the longest length of stay being 33 days. With regard to our

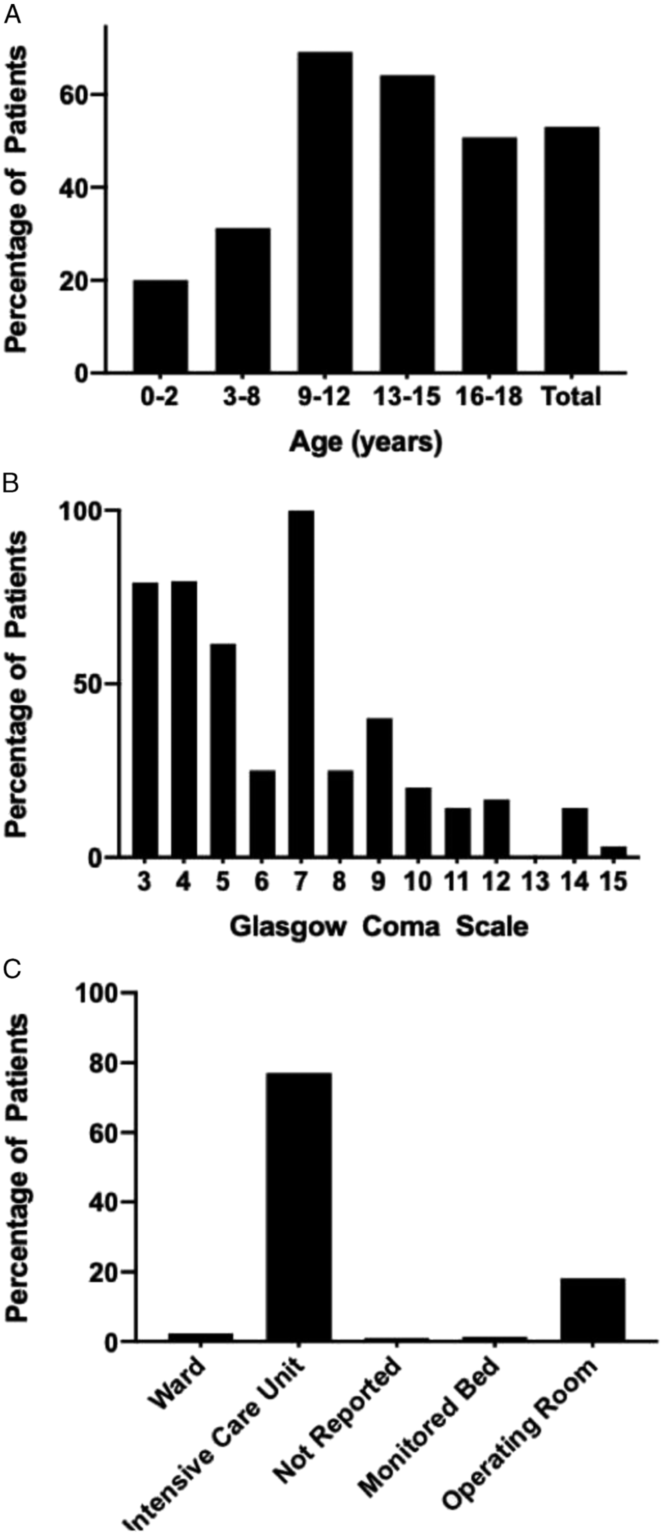

Figure 4. Clinical outcomes. (*A*) Mortality by age (percent). (*B*) Mortality by GCS. (*C*) Emergency room disposition (percent).

primary outcome, seven of these patients died, representing a mortality of 10.8% for the modifiable injury group. None of the 13 patients aged 0 to 12 years in the GCS scores of 9 to 15 subgroup died.

There were a lower number of recorded complications in the modifiable injury group as well, with two urinary tract infections, one unplanned intubation, one unplanned return to the operating room, one deep vein thrombosis, and one decubitus ulcer. It is noteworthy that there were no instances of pneumonia or cardiac arrest in this group of patients.

Our only means of estimating functional outcome was discharge location, with the assumption that patients who were ultimately discharged home had better functional outcome than patients who were discharged to other inpatient facilities. The only significant difference in discharge disposition in this regression was GCS score of 3 versus those with GCS scores of 13 to 15 (OR, 32.5; CI, 6.38–165.64). There were no significant differences for other factors, including age, craniotomy, ICP monitor insertion, sex, insurance, presence of shock, or ethnicity, nor were there any differences observed in our modifiable injury group (Table 3).

DISCUSSION

Currently, there are very little data to support clinical decision making in this particular population. Current management of pediatric CGI is in accordance with severe brain trauma guidelines. The Surviving Penetrating Injury to the Brain score, a risk stratification tool,[16] considers the following associations with lower risk: higher motor GCS, normal pupil examination, non–self-inflicted wounds, female patients, lower ISS, International Normalized Ratio under 1.3, and transfer from another institution. The literature supports these risk factors (GCS, pupil reaction, and hemodynamics) as important predictors of prognosis;[14,17,18] however, the aforementioned tool and the majority of the literature places focus on adult patients.

The current study suggests that typical measures of prognostication in trauma are potentially unhelpful in children with CGI. For example, vital signs were within normal limits for the

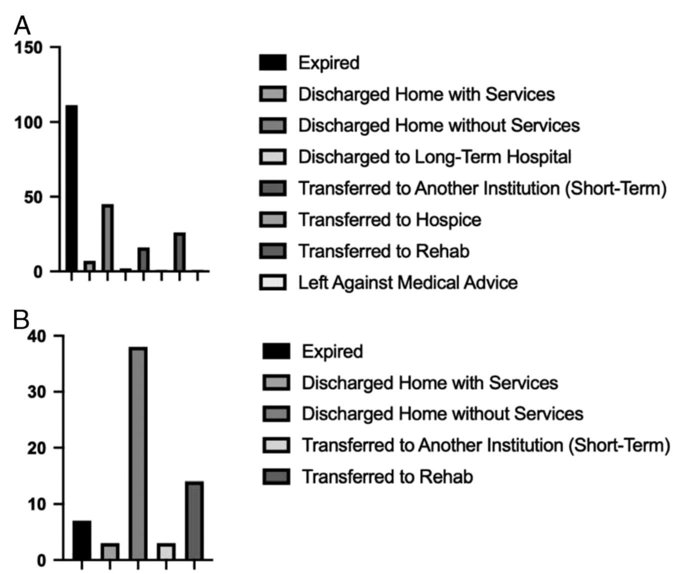

Figure 5. Functional outcome—discharge location frequency. (*A*) Frequency of discharge location overall. (*B*) Frequency of discharge location in modifiable injury group.

TABLE 1. Characteristics of Patients Included in the National Trauma Database Query

Age	0–2 y, n (%)	3–8 y, n (%)	9–12 y, n (%)	13–15 y, n (%)	16–18 y, n (%)	Total, n (%)
Frequency	5 (2.39)	16 (7.66)	13 (6.22)	53 (25.36)	122 (58.37)	209
GCS score						
3	1 (20)	5 (31.25)	8 (61.54)	31 (58.49)	56 (45.9)	101 (48.33)
4–8	0	5 (31.25)	2 (15.38)	10 (18.87)	26 (21.31)	43 (20.57)
9–12	2 (40)	3 (18.75)	0	4 (7.55)	14 (11.48)	23 (11.0)
13–15	2 (40)	3 (18.75)	3 (23.08)	8 (15.09)	26 (21.31)	42 (20.1)
Shock on presentation	2 (40)	4 (25)	3 (23.08)	17 (32.08)	33 (27.05)	59 (28.23)
Race						
White	0	1 (6.25)	7 (53.85)	32 (60.38)	47 (38.52)	87 (41.63)
African American	5 (100)	11 (68.75)	4 (30.77)	15 (28.3)	51 (41.8)	86 (41.15)
Other	0	4 (25)	2 (15.38)	6 (11.32)	24 (19.67)	36 (17.22)
Primary payer						
Private	1 (20)	3 (18.75)	8 (61.54)	26 (49.06)	56 (45.9)	94 (44.98)
Government	4 (80)	11 (68.75)	5 (38.46)	21 (39.62)	54 (44.26)	95 (45.45)
Other	0	2 (12.5)	0	6 (11.32)	12 (9.84)	20 (9.57)
Mortality	1 (20)	5 (31.25)	9 (69.23)	34 (64.15)	62 (50.82)	111 (53.11)

majority of patients, with only 28.2% of patients presenting with shock in the overall group and 12.3% in our modifiable injury group. Shock did not correlate with mortality in the regression analysis. This may be due to unique compensation mechanisms seen more frequently in children, but it is important to recognize that normal vital signs should not prevent aggressive management in these patients.

Previously published data have shown that patients with a GCS score of 3 have significantly higher mortality rates, suggesting avoidance of aggressive treatment in this particular group of patients. A recent systematic review reported 90.3% mortality in this group, as compared with 7.7% mortality for patients with GCS scores of 14 and 15.[9] By contrast, this large-scale retrospective analysis finds that nearly half of these patients have GCS score of 3 on arrival. Mortality rates for these patients were lower than previously reported, at 79.2%; however, this remains significantly higher than patients presenting with a GCS score of 4 and above, in keeping with previous literature. Interestingly, there was no significant difference in mortality between patients with a GCS score of 3 and those with GCS scores of 4 to 8, with a similar finding when comparing GCS scores of 9 to 12, to 13 to 15. The overall mortality rate for patients with GCS scores of 13 to 15 in our study was also lower than previous literature would suggest, at 1.8%. Overall, patients may not do as poorly as previous evidence has suggested.

Pediatric patients aged 0 to 8 years demonstrated a significantly lower presenting GCS pattern (Fig. 2) and subsequent lower mortality rate compared with older children. It may be that the aforementioned physiologic factors in younger children allow for penetrating brain injuries to be less damaging than in

TABLE 2. Logistic Regression Analysis of Odds Ratios for Mortality (95% CIs)

All Patients				GCS 9–15 Subgroup		
Category	Estimate	CI Lower	CI Upper	Estimate	CI Lower	CI Upper
Age 3–8 y vs. 0–2 y	0.692	0.012	38.492	0.192	<0.001	>999.999
Age 9–12 y vs. 0–2 y	1.454	0.022	94.473	0.089	<0.001	>999.999
Age 13–15 y vs. 0–2 y	0.806	0.016	39.701	>999.999	<0.001	>999.999
Age 16–18 y vs. 0–2 y	0.508	0.011	23.581	>999.999	<0.001	>999.999
Shock	1.061	0.426	2.639	<0.001	<0.001	>999.999
ICP monitor	**0.267**	**0.082**	**0.864**	0.65	0.038	11.054
Craniotomy	**0.232**	**0.068**	**0.796**	0.201	0.013	3.024
Male vs. female	2.009	0.566	7.13	1.752	0.204	15.011
African American vs. White	0.632	0.247	1.617	0.789	0.081	7.678
Other vs. White	0.395	0.113	1.375	1.326	0.104	16.977
Government insurance vs. private	**0.33**	**0.134**	**0.812**	0.882	0.13	5.993
Other insurance vs. private	2.402	0.423	13.628	<0.001	<0.001	>999.999
GCS 4–8 vs. 3	0.458	0.176	1.195			
GCS 9–13 vs. 3	**0.131**	**0.033**	**0.524**			
GCS 14–15 vs. 3	**0.007**	**0.001**	**0.038**			

Statistically significant results are bolded.

TABLE 3. Logistic Regression Analysis of Odd Ratios for Discharge Disposition (Home vs. Other Inpatient Location, 95% CIs)

All Patients				GCS 9–15 Subgroup		
Category	**Estimate**	**CI Lower**	**CI Upper**	**Estimate**	**CI Lower**	**CI Upper**
Age 3–8 y vs. 0–2 y	5.036	0.250	101.432	3.138	0.110	89.292
Age 9–12 y vs. 0–2 y	3.653	0.073	183.143	>999.999	<0.001	>999.999
Age 13–15 y vs. 0–2 y	1.444	0.080	26.071	0.512	0.028	9.500
Age 16–18 y vs. 0–2 y	2.483	0.161	38.369	2.143	0.143	32.215
Shock	1.815	0.468	7.046	4.955	0.377	65.123
ICP monitor	0.707	0.196	2.551	0.596	0.089	3.998
Craniotomy	1.093	0.297	4.019	0.656	0.107	4.012
Male vs. female	1.591	0.302	8.385	2.534	0.299	21.503
African American vs. White	0.881	0.234	3.317	0.443	0.070	2.794
Other vs. White	0.674	0.145	3.140	0.758	0.085	6.729
Government insurance vs. private	2.775	0.855	9.009	2.535	0.565	11.383
Other insurance vs. private	0.623	0.063	6.155	0.566	0.046	6.975
GCS 4–8 vs. 3	2.660	0.559	12.671			
GCS 9–13 vs. 3	4.681	0.886	24.728			
GCS 14–15 vs. 3	**32.500**	**6.377**	**165.642**			

Statistically significant results are bolded.

older children and adults, precluding the use of data from adults for guidance in this population. Alternatively, initial lower GCS may reflect the severity of CGI and suggest that some of these patients do not survive for transport to hospital. Regardless, from the perspective of the consultant confronted with this challenging presentation, these data suggest a higher survival rate for younger patients with this injury pattern than previously accepted.

Interestingly, patients with government insurance had an apparently lower risk of death compared with those with private insurance. Further study on etiologies for this disparity may be warranted. Speculation on mechanisms for this difference is not yet possible without improved evidence.

The most compelling finding was the significant difference in mortality for all patients who underwent craniotomy or placement of an ICP monitor. This suggests that at least some pediatric CGI patients may benefit from aggressive treatment and invasive monitoring. This is further supported with morbidity outcome findings, where surviving patients had favorable functional outcomes with short hospital admissions, and the majority of patients gained functional independence at home or were discharged to a less acute rehabilitation facility. However, this study is limited because there were no specific clinical measures of functional outcome available for analysis. Our only available estimate of functional outcome was discharge disposition. Through this limited analysis, there was an observed significant difference between surviving patients presenting with a GCS score of 3 and those with GCS scores of 13 to 15. This does provide insight to the functional dependence patients surviving severe injuries may face. It is important to note that patients with less severe injury, specifically those with presenting GCS scores of 13 to 15 are 32.5 times more likely to be discharged home, as opposed to an inpatient facility. This may assist in goals of care discussions with families and health care provider decision making.

We noted higher rates of craniotomy and ICP monitor insertion in the modifiable injury subgroup (GCS score, >9; ISS, >16) compared with the overall group. There may be selection bias as a result of this, given the retrospective nature of this study. Perhaps there is a survival benefit for surgery in patients with lower GCS that we are unable to appreciate as a result of selection bias toward higher GCS patients undergoing surgical procedures in this population.

Limitations

Limitations of this study are numerous and should be considered in interpretation of these data. There are residual confounding factors inherent to the retrospective nature of this study. A high proportion of patients are from older age groups. This is a common finding within the literature for this population, and thus, literature is biased toward older teens, which may skew outcomes toward more similar findings to adults. Because of data analysis relying on a database, there may be incomplete or inaccurate data. For this study, patients with incomplete data sets were excluded, which may have affected our overall prevalence. Selection bias may also exist, as the NTDB excluded patients who died at the scene. However, the incidence of pediatric gunshot trauma is likely to be more accurate than their adult counterpart, as, irrespective of injury severity, pediatric CGIs are more likely to be transferred to hospital for continued resuscitation.

There may be further identifiable prognostic factors in this population that were not isolated here as a result of lack of physiologic data, such as pupil reactivity, mechanistic details of injury (i.e., self-inflicted, ballistics information), capability of treating center (i.e., level of trauma center or pediatric vs. adult center), or coagulation profile data. Specifically, a lack of granularity and reliability within the NTDB exists to address some very pertinent questions. There is an inability to reliably differentiate between craniotomy and decompressive craniectomy specifically. There was also no further description beyond "other procedures," which certainly introduces potential confounding variables that cannot be defined in our population. Reported GCS is taken as stated and may be confounded by difficulty in measuring pediatric GCS in emergent scenarios, which could bias these results. Importantly, increased granularity and the evolution of detailed databases may allow for appropriately powered subgroup analysis to determine the specifics of benefit for procedures such as craniectomy or ICP monitoring compared with both age and GCS. Recommendations and conclusions within the scope of this article show benefit but without definitive proof of which subgroups have the greatest benefits and which may not be salvageable. The availability of results on a larger scale for these subgroups would allow future stronger recommendations on utility and benefits in pediatric CGI within the known framework of ICP monitoring per Brain Trauma Foundation guidelines.

While an accurate depiction of intracranial gunshot wound was used in considering *International Classification of Diseases, Tenth Revision*, codes for this study, patients may be missed because of variable injury pattern as well.

CONCLUSION

This study uses the NTDB to quantify the prevalence of pediatric CGI and attempt to identify prognostic factors. It highlights the dramatic differences within the pediatric populations and expands on recent literature analysis. Patients aged 0 to 8 years seem to present with significantly better initial GCS and subsequently lower mortality rates. Lower presenting GCS was associated with higher mortality, although a threshold for nonsurvival was not identified. The 79% mortality rate in patients with a GCS score of 3 on presentation suggests that, outside of a declared neurologic death, ICP monitoring and treatment measures including craniotomy should be considered by the consulting clinician. Of surviving patients, nearly all were discharged home or to a rehabilitation facility within a short time (mean admission, 8.7 days). There was a significant difference between patients with most severe injury (GCS score, 3) and those with mild injury (GCS score, 13–15) in terms of discharge disposition, with increased likelihood of patients with mild injury being discharged home, suggesting aggressive intervention would be most beneficial in this group of patients.

Subgroups most likely to benefit from specific treatment should be analyzed through further tracking of national and international trauma data to determine prognostic benefit and cases with high mortality, regardless of intervention. Definitive demonstration of a subgroup who will not survive would be particularly beneficial for clinicians, as early data here suggest that mortality may be more modifiable than previously presumed.

AUTHORSHIP

M.M.L. contributed in the literature search, study design, data interpretation, writing, and critical revisions. T.D. contributed in the literature search, study design, data interpretation, writing, and critical revisions. A.M. contributed in the study design, data interpretation, and critical revisions. P.T.E. contributed in the study design and critical revisions. S.V.S. contributed in the study design, data collection, data analysis, data interpretation, and critical revisions. All authors approved of the final manuscript.

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DISCLOSURE

The authors declare no conflicts of interest.

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