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Evaluation of the Relationship Between Mechanism of Injury and Outcome in Pediatric Trauma

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Abstract

Background—Most prehospital triage strategies are based on physiologic, anatomic, and mechanism-related variables. Although previous studies have suggested the value of physiologic and anatomic triage criteria, the predictive capacity of mechanism of injury has been questioned. The purpose of the current study was to evaluate the relationship between mechanism of injury and resource utilization and outcome among injured children treated at trauma centers.

Methods—The relationship between mechanism of injury and mortality and resource utilization (need for operative care, total and ICU length of stay) was analyzed using the records of pediatric patients (age <15 years) included in the National Pediatric Trauma Registry between 1995 and 2001.

Results—Significant variability in the outcome, resources requirements, and need for inpatient rehabilitation after discharge were observed among the mechanisms analyzed. Mechanisms such as firearm injuries were more likely to be severe and require significant trauma center resources, whereas other mechanisms such as falls related to stairs were more likely to result in injuries that were less severe and require relatively few resources. A proposed framework is presented into which mechanisms are stratified according to severity of injury (high vs. low severity) and need for trauma center resources (high vs. low requirement).

Conclusions—Mechanism of injury is associated with the need for trauma center care but this association is highly dependent on the measure used to determine appropriateness of triage.

Keywords

Wounds and injury; Child; Hospital mortality; Models; Statistical; Triage; Outcome assessment

Recent studies suggest that moderate to severely injured children may have better outcomes when treated at trauma centers, particularly those with a pediatric expertise.^{1,2} The reasons for these observations have not been systematically studied but likely relate to the resources and experience available at trauma centers. Despite evidence of an advantage of trauma center care, even severely injured children may not be directly transferred to a trauma center

from the site of injury.³ Prehospital providers may initially select a nontrauma center because of the presence of immediate life-threatening injuries, the distance from the injury scene to the nearest medical center, or prehospital provider preferences. To enhance appropriate transfer to trauma centers, triage guidelines and scoring systems have been proposed for assisting prehospital providers.^{4,5} These guidelines generally have included criteria based on mechanism of injury, specific anatomic sites of injury, or evidence of deranged physiology.

Although previous studies have supported the use of anatomic and physiologic criteria, the importance of mechanism of injury as a criterion for prehospital triage has been challenged. In an evaluation of triage criteria proposed by the American College of Surgeons, Cooper et al. observed that patients triaged based on mechanism alone uncommonly had severe injuries.⁶ Of note, most patients with a triage criteria based on mechanism also had other anatomic or physiologic criteria suggesting severe injury. Esposito et al. observed that the capacity of mechanism as a sole factor for predicting mortality was highly variable.⁷ High yield mechanism criteria for mortality included pedestrian injuries and motor vehicle occupant injuries, whereas low yield criteria included motor vehicle rollover. Santaniello et al. observed that mechanism of injury alone resulted in significant undertriage with respect to mortality and severity of injury.⁸ Mechanism, however, was observed to be a strong predictor of the need for trauma center resources including immediate operating room availability and the need for critical care.

As a prerequisite to determining the potential of mechanism as a pediatric-specific trauma triage criteria, the relationship between mechanism of injury and outcome in injured children needs to be defined. Studies addressing the relationship between mechanism of injury and outcome have been mainly based on data from adult rather than pediatric trauma patients. Triage criteria developed for adults may not be appropriately used for children because of age related differences in mechanism of injury and differences in the anatomic site and severity of the same mechanism in different age groups. Mechanisms that are identified as being associated with a high likelihood of worse outcome or high resource utilization in children will be ideal for inclusion as potential criteria in a pediatric-specific trauma triage system.

The purpose of this study was to evaluate the relationship between features of the mechanism of injury (including type of injury, intent of injury, and actual mechanism) and outcome (mortality), resource utilization, and need for inpatient rehabilitation after discharge among pediatric trauma patients evaluated at pediatric trauma centers. Using the results from the current study as a starting point, we plan subsequent studies that will address the interaction of mechanism of injury with anatomic injuries and post injury physiology in predictive models of trauma outcome.

METHODS

Study Design

This study was a retrospective review of the records of injured children recorded in the National Pediatric Trauma Registry (NPTR), a large, national trauma database. This study

has been approved by the Institutional Review Board at the University of Medicine and Dentistry of New Jersey-Robert Wood Johnson Medical School.

Setting and Selection of Participants

Data were obtained from the NPTR, a database started in 1985 that tracked the management and outcome of injured children treated at participating pediatric trauma centers or pediatric hospitals. Data ($n = 50,199$) from the registry obtained between 1995 and 2001 were used. To restrict the analysis to pediatric trauma patients typically evaluated by most trauma services, patients >14 years old ($n = 7,202$) and those with an external cause of injury code (E-code) representing injury by poisoning, drowning, overexertion, or burns ($n = 31$) were not included.

Outcome Measures

The principal measure of patient outcome that was evaluated was in-hospital death. Cause of death, time until death, and site of death (emergency department, operating room, or other) were also evaluated because each may have different implications for initial triage. Resource utilization was evaluated using intensive care unit (ICU) and hospital length of stay (LOS) and the need for surgical treatment. Because of its importance in previous studies as a triage criterion, injury severity (Injury Severity Score [ISS] ≥ 15) was also analyzed. To determine the long-term impact of injury, the need for inpatient rehabilitation after discharge was recorded.

Primary Data Analysis

Variables were extracted from the database including age, gender, type of injury (blunt, penetrating, or other), external cause of injury (E-code), ISS, emergency department and discharge disposition, length of ICU stay, total LOS, mortality, time until death, and cause of death (central nervous system injury-related, hypoxia, hypovolemia or hemorrhage, multiple organ failure, or other/unknown). E-codes were used to assign a mechanism and intent (assault, self-inflicted, unintentional, or undetermined/other) using the framework recommended by the Centers for Disease Control for presenting injury mortality data.⁹ Because of their importance as a mechanism of injury among children, falls were further classified as previously described into falls from a building, falls from furniture, falls from playground equipment, falls from stairs, other falls from heights, falls on the same level, and other/unspecified falls.¹⁰ Children with injuries related to an off-road motor vehicle (E821) were identified among those injured by other modes of transportation ("transport, other") based on the high morbidity and mortality associated with this mechanism in children.¹¹

SPSS 12.0 (SPSS, Chicago, IL) was used for all statistical calculations. Differences between groups were compared using Fisher's exact test. Continuous variables were analyzed using the Student's t test. Significance was defined as $p < 0.05$. Kaplan-Meier product limit method was also used to analyze mortality. Survivors were censored when discharged from the hospital. Survival rates were compared using the log rank test with significance defined as $p = 0.005$ to account for multiple comparisons.

RESULTS

Characteristics of Study Patients

In the study, 42,966 injured children were identified, 63.6% of whom were male. The average age was 6.8 ± 4.2 years. Most children were transferred from the scene of injury and not transported from another hospital ($n = 25,898$, 60%). More injuries were caused by blunt (93.1%) than either penetrating (6.7%) or other mechanisms (0.2%). Penetrating injuries were most frequent among children injured by a cut/pierce, firearm, machinery, or natural/environmental mechanism. Unintentional injuries (93.1%) were more frequent than injuries caused by assaults (5.8%), self-inflicted intent (0.2%), or undetermined intent (0.9%). Assaults were most common among children injured by a firearm, those being struck by a nonfalling object, and child abuse. Self-inflicted injuries were most frequent among those injured by a firearm or by suffocation.

There were 1,232 deaths (2.9%). Children who died were younger (5.9 ± 4.4 vs. 6.7 ± 4.2 years, $p < 0.001$) and more commonly male (40.0% vs. 36.6%, $p = 0.02$) than those who survived. Central nervous system injury was the leading cause of death followed by hypoxia, hemorrhage or hypovolemia, multiple organ failure, and other or unknown causes (Table 1). There was no significant difference in the overall mortality or cause of mortality among children transported from the scene or transferred from another facility.

A similar percentage of deaths among children sustaining either a blunt or penetrating injury were caused by a central nervous system cause (73.4% vs. 67.5%, $p > 0.05$). Death among children sustaining a penetrating injury was more commonly caused by hypovolemia or hemorrhage than it was for those dying from a blunt injury (16.9% vs. 5.8%, $p < 0.001$). Compared with deaths caused by other intents, deaths caused by self-inflicted injuries were less commonly from a central nervous system (CNS) cause and more commonly from hypovolemia or hemorrhage (Table 1), consistent with the high percentage (45%) of penetrating injuries among children with self-inflicted injuries. More than 25% of deaths caused by a cut/pierce, machinery, or motorcycle mechanism were the result of hypovolemia or hemorrhage (Table 1).

Death occurred most rapidly in children dying of hypovolemia or hemorrhage (Fig. 1). Mean survival time was 17 hours (95% confidence interval [CI], 5–29 hours) for children dying of hypovolemia or hemorrhage, 29 hours (95% CI, 17–42) for those dying of other or unknown causes, 52 hours (95% CI, 43–60) for those dying of CNS injury, 59 hours (95% CI, 38–81) for those dying of hypoxia, and 73 hours (95% CI, 29–117) for those dying of multiple organ failure. Mean survival time overall was significantly longer among those transferred from another facility than those transported from the scene (62 hours vs. 40 hours, $p < 0.001$). A significant difference was also observed by transfer status among those who died of hypovolemia or hemorrhage, CNS injury, and hypoxia but not among those who died of multiple organ failure or other causes.

Relationship Between Mechanism of Injury and Mortality

We first examined the relationship between mechanism of injury and mortality. Blunt and penetrating injuries had a similar mortality (Table 2) and time until death (Fig. 2A). Patients

injured by a penetrating or blunt mechanism had a lower mortality ($p < 0.001$, Table 2) and died later after injury (Fig. 2A) than did those with other types of injury. Although there was no significant difference in mortality among those sustaining a blunt or other type of injury and transfer status, children with penetrating injuries who arrived from the scene had a higher mortality than those transferred from other facilities (3.2% vs. 1.9%, $p = 0.03$). Self-inflicted injuries had a higher mortality than injuries caused by other intents ($p < 0.001$, Table 2), with most deaths occurring within the first 24 hours after admission (Fig. 2B). Unintentional injuries had the lowest mortality ($p < 0.001$, Table 2). Children who were transferred from another facility after an assault had a higher mortality than those arriving from the scene (12% vs. 8%, $p = 0.001$), whereas transfer status had no significant association with mortality among injuries caused by other intents.

The relationship between mechanism of injury and mortality was further analyzed after grouping by intent. Assaults caused by either firearms or child abuse had a higher mortality than assaults caused by other mechanisms (Table 2). Ninety-one percent (21 of 23) of deaths caused by an assault by a firearm and 48% (108 of 227) of deaths caused by child abuse occurred within the first 24 hours after admission (Fig 3A). Firearm injury and suffocation generally had the highest mortality among children injured by self-inflicted, unintentional, or undetermined intent. The mortality of firearm and suffocation injuries was similar among those with self-inflicted and undetermined intents, whereas the mortality of unintentional suffocation injuries was higher than unintentional firearm injuries (Table 2, Fig. 3B–D).

No significant difference in emergency department or operating room mortality was observed among children with either a blunt or penetrating type of injury. Children sustaining a self-inflicted injury had a significantly higher emergency department mortality than those injured by other intents ($p < 0.001$, Table 3). No significant differences were observed in the percentage of children dying in the operating room after injury by any intent. Injuries caused by firearms, pedestrian accidents, and suffocation had the highest emergency department mortality, whereas injuries caused by firearms, child abuse, and suffocation had the highest hospital mortality (Table 3). The highest percentages of deaths in the operating room were observed among children injured by a firearm or in a motorcycle crash (Table 3). Children who were received from the scene had higher emergency department mortality than those transferred from another hospital (0.9% vs. 0.2%, $p < 0.001$). No significant difference in operating room mortality based on transfer status was observed.

Relationship Between Mechanism of Injury and Resource Utilization

We next evaluated the relationship between mechanism of injury and resource utilization as measured by timing of and need for operative treatment and ICU and total LOS. Children injured by a penetrating injury more frequently went to the operating room directly from the emergency department ($p < 0.001$) and more frequently required surgery during their hospitalization ($p < 0.001$) than did those injured by a blunt or other mechanism (Table 3). Patients with unintentional injuries more commonly went to the operating room directly from the emergency department than those injured by an assault or undetermined cause ($p < 0.001$, Table 3). No significant difference in the need for immediate surgery was observed between those sustaining either an unintentional or self-inflicted injury. Children sustaining

an unintentional injury more commonly required surgical treatment during hospitalization than those sustaining injury by any other intent ($p < 0.005$).

Depending on the mechanism, the percentage of children requiring immediate surgery ranged from 0% to 5%, and the percentage requiring surgery at any time during hospitalization ranged from 4% to 69% (Table 3). Mechanisms associated with a higher percentage of penetrating injury (including cut/pierce, firearm, machinery, and natural/environmental mechanisms) more often required either immediate surgery or surgery at any time during hospitalization. Among mechanisms caused only by a blunt type of injury, falls from playground equipment most often required immediate or delayed surgery ($p < 0.001$). Compared with children arriving from the scene, those transferred from another facility were significantly more likely to require immediate (20.4% vs. 19.4%, $p = 0.01$) or delayed operative treatment (42% vs. 37%, $p < 0.001$).

Patients injured by a penetrating mechanism had a shorter ICU LOS (0.8 ± 3.5 vs. 1.0 ± 3.5 days, $p = 0.01$) but longer total LOS (4.2 ± 6.5 vs. 3.8 ± 6.6 days, $p = 0.003$) than those with a blunt mechanism did. The ICU and total LOS were longer among children injured in an assault compared with those injured by undetermined or unintentional intent ($p < 0.001$), but were not significantly different compared with those sustaining a self-inflicted injury (Table 3). Compared with children sustaining an unintentional injury, children sustaining a self-inflicted injury had a longer ICU LOS ($p = 0.02$) but not a significantly longer total LOS ($p > 0.05$). Children injured by a firearm, suffocation, and child abuse had the longest ICU LOS, whereas those injured by a firearm, machinery, or child abuse had the longest total LOS (Table 3). Children transferred from another hospital had a significantly longer total LOS (4.3 ± 7.4 vs. 3.5 ± 6.0 days, $p < 0.001$) and ICU LOS (1.2 ± 3.7 vs. 0.9 ± 3.2 days, $p < 0.001$) than those transported directly from the scene.

Relationship Between Mechanism of Injury and Injury Severity and Disability

We next analyzed the relationship between mechanism of injury and injury severity (ISS) and the need for post-discharge rehabilitation. Children injured by a penetrating injury less commonly had an ISS ≥ 15 than those injured by a blunt mechanism (8% vs. 16%, $p < 0.001$). Fewer children injured unintentionally had an ISS ≥ 15 than did those injured by other intents ($p < 0.001$). No difference in the percentage of children with an ISS ≥ 15 was observed among those injured by an assault, self-inflicted, or undetermined intent (Table 3). Severe injuries were highest among children injured by firearms (27%), unspecified motor vehicle traffic crashes (28%), suffocation (26%), and child abuse (48%) and lowest among those injured by a cut/pierce (3%) mechanism or by a fall related to playground equipment (3%). Children transferred from other hospitals were significantly more likely to have an ISS ≥ 15 than those arriving from the scene (20% vs. 13%, $p < 0.001$).

Among survivors, discharge to a rehabilitation facility was more common among children sustaining a blunt compared with penetrating injury ($p < 0.001$, Table 3). Children with self-inflicted injuries more commonly required inpatient rehabilitation care after discharge than did those with injuries by other intents ($p < 0.02$). No significant differences were observed among those injured by other intents. Children injured by a firearm or in a motor vehicle traffic crash generally had the highest rates of transfer to a rehabilitation facility, whereas

those injured in a fall had the lowest (Table 3). No significant difference was observed in the need for rehabilitation after discharge based on transfer status.

DISCUSSION

The priorities of prehospital triage need to be better delineated for injury children. After severe injuries, there may be an immediate need to transport to a facility that can provide rapid care in 'the golden hour'. This need can be measured in several ways including death in the emergency department or early after admission, the need for immediate transfer to the operating room, or death in the operating room. In addition, severe injuries that are not associated with early mortality or immediate surgery might also benefit from the nonoperative care available in trauma centers immediately after injury. Injuries with a high likelihood of requiring significant hospital resources might also benefit from trauma center care even if this is not immediately required. Measures that might indicate this need include total LOS and ICU LOS, the need for a surgical procedure during admission, and overall mortality. Although LOS is affected by factors other than the actual medical need (including local and provider practice patterns, availability of rehabilitation or in-home services after discharge, and social factors), the need for operative care and mortality are more objective measures of the potential need for hospital resources. Finally, children at high risk for long-term disability as evidenced by the need for inpatient rehabilitation after discharge may also benefit from the increased resources of a trauma center. The focus of the current study was to identify mechanisms that have a high likelihood of requiring trauma center care as evidenced by poor outcome or high resource needs.

We observed that the features of the injury (type, intent, and mechanism) provide important insight into outcome and resource utilization. Although hospital mortality, site of mortality, and time until death were similar between children injured by blunt and penetrating mechanisms, other measures of outcome and utilization differed. Compared with those sustaining penetrating injuries, children sustaining blunt injuries were more severely injured, required more acute care days and were more likely to require rehabilitation after discharge. Patients injured by a penetrating mechanism, however, more frequently required immediate or delayed surgical care and had a longer total LOS.

Differences in resource utilization and outcome were also observed among children injured by different intents. Unintentional injuries were more frequent than those caused by other intents, with most being caused by a motor vehicle traffic crash. Children sustaining unintentional injuries were less severely injured and required fewer critical care days but more commonly required either immediate or delayed surgical care. Self-inflicted injuries were associated with a higher mortality than were those caused by other intents with most deaths occurring either in the emergency department or on the first day of admission. The reason for the high mortality of self-inflicted injuries likely relates to the mechanism of these injuries—gunshot wounds to the head and suffocation by hanging. In addition to being associated with high, early hospital mortality, self-inflicted injuries more often required inpatient rehabilitation after discharge showing the high morbidity and potential long-term impact of these injuries. Although resource utilization and severity of injury were similar

between self-inflicted injuries and assaults, the early and overall mortality of self-inflicted injuries were higher.

Although intent of injury has received little attention as a potential triage criterion, we think that the current study supports a potential role for this variable. Determination of intent of injury may be difficult in the field but in many cases may be evident to prehospital providers. As a qualifier for the mechanism of injury, intent provides additional insight into the potential severity of injury, with injuries related to assaults and self-inflicted injuries generally being more severe than those caused by other intents. The importance of intent as a predictor may be obviated by anatomic or physiologic data but may be useful when these data cannot easily be obtained or are not available.

We observed diverse patterns of outcome and resource utilization among the different mechanisms of injury. The mechanisms associated with the highest values of each measure are shown in Table 4. In many cases, the mechanisms listed in each column will be intuitive to those caring for injured children. To facilitate comparison of the impact of different mechanisms of injury, we considered a classification according to the severity of injury (e.g. ISS or mortality rate) and the level of trauma center resources required (e.g., need for surgical care or ICU days, Fig. 4). For example, firearm injuries were associated with a high ISS and mortality and required significant trauma center resources, whereas falls on stairs were associated with less severe injury and required fewer resources. Although suffocation injuries were associated with severe injury and high mortality, resource utilization was not the highest among all mechanisms, likely related to early mortality among these patients. Although cut/pierce injuries were more likely to be less severe and less likely to result in death, these injuries frequently required immediate or delayed surgical care.

Using classification based on injury severity and resource utilization, we have proposed initial recommendations about the appropriateness of immediate or delayed triage to a trauma center (Fig. 4). Mechanisms associated with a high potential for severe injury or death ideally should be treated at a trauma center. Similarly, those mechanisms associated with a high likelihood of requiring trauma center resources would benefit from trauma center care. In contrast, mechanisms associated with neither high injury severity nor requiring significant resource utilization may initially be treated at the nearest available hospital regardless of trauma status. Firearm injuries, motorcycle crashes, and all-terrain vehicle crashes are representative mechanisms associated with both a high likelihood of both severe injury and high resource utilization, whereas falls on stairs and pedal cyclist accidents not related to a motor vehicle are representative of mechanisms with a low likelihood of both.

In applying this model in a real world setting, mechanism of injury obviously would not be the sole factor determining where to direct an injured child. The location of any mechanism of injury on this matrix would be modified by additional information obtained about the anatomic site of injury and post-injury physiology. Although we have presented a 2×2 matrix, the dimensions could be modified to more specifically reflect resource requirements and injury severity. In addition, the recommendation for triage will vary according to the available triage options in a given region. In an area with a single facility, this matrix could

be used to direct the level of care upon arrival. In regions with several hospitals with variable pediatric expertise (such as nontrauma centers, adult trauma centers with or without pediatric expertise, or pediatric trauma centers), recommendations could be modified to direct children to the most appropriate center based on the nature of their injury and its consequences.

The current study highlights several challenges that will arise when developing a pediatric-specific triage tool. Children are injured by heterogeneous mechanisms that have variable outcomes and requirements for trauma center resources. For this reason, selection of mechanisms for potential inclusion in a triage protocol based solely on injury severity may not accurately reflect the requirements for trauma center care. There is a need to define priorities for triage based on both the availability of resources and the impact of these resources on short- and long-term outcome. Additional study is needed to define the relative importance of these measures with the initial triage decision. The use of triage criteria that are either 'present' or 'absent' or triage systems based on calculation of a score may not accurately predict the complex requirements of the injured child. The next generation of triage tools should focus on the interactions among mechanism of injury, anatomic site of injury, and physiology and their ability to predict outcome. It may be more appropriate to replace a simple set of triage criteria or a triage score with a computer based tool that has a simple interface but conveys the complexity of the injured child and their need for trauma center resources.

The NPTR has several advantages as a data source for this study including the large size of the database, the geographic diversity of hospitals represented, and the availability of several variables (including cause of death, time until death, and a written description of the mechanism of injury) that are not in other databases. These factors facilitate the analysis presented in this article. The NPTR, however, is a biased sample because it contains records obtained almost exclusively from hospitals with an interest in the care of injured children. Nontrauma centers and adult trauma centers with limited pediatric expertise are not represented in these data, potentially leading to unbalanced estimates of relative resource needs. The ideal dataset would be drawn from an inclusive trauma system containing data from all providers. In addition, the relationship between mechanism and outcome were presented in the current study without considering the importance of related anatomic or physiologic triage criteria. The intent of this study, however, was to identify mechanisms with predictive value that will later be evaluated for interactions with anatomic and physiologic factors in future studies.

In conclusion, we have profiled the relationship between features of the mechanism of injury and both resource utilization and outcome. A matrix depicting injury severity and resource utilization can be used to model the potential need for trauma center care. Although children injured by some mechanisms have a poor outcome and require considerable resources, the outcome and requirements of others are more variable. Our findings suggest that mechanism of injury may be a useful addition to a pediatric trauma triage tool. Although mechanism of injury cannot and should not be viewed as a stand alone triage criterion, we think that our findings will be useful when designing the next generation of triage tools that include mechanism in addition to other criteria. Further study will be needed to evaluate how

anatomic site of injury and physiology interact with mechanism to predict the need for trauma center care and determine the independent contribution of mechanism of injury as a triage predictor.

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Fig. 1.

Overall survival rates according to cause of death (Kaplan–Meier estimates). Overall: $p < 0.001$. Pairwise: CNS versus hypovolemia/hemorrhage, $p < 0.001$; hypoxia versus hypovolemia/hemorrhage, $p < 0.001$; multiple organ failure (MOF) versus hypovolemia/hemorrhage, $p < 0.001$, other/unknown versus hypovolemia/hemorrhage, $p = 0.03$; CNS versus other/unknown, $p < 0.001$; hypoxia versus other/unknown, $p = 0.009$; MOF versus other/unknown, $p = 0.03$; $p > 0.05$ for other combinations.

Fig. 2.

Overall survival rates according to type (A) and intent (B) of injury (Kaplan–Meier estimates). (A) Blunt versus penetrating, $p > 0.05$; blunt versus other and penetrating versus other, $p < 0.001$. (B) Assault versus unintentional, $p < 0.001$; assault versus self-inflicted, $p < 0.001$; assault versus undetermined, $p = \text{NS}$; undetermined versus self-inflicted, $p < 0.001$; unintentional versus self-inflicted, $p < 0.001$; unintentional versus undetermined, $p < 0.001$.

Fig. 3.

Overall survival rates among children injured by assault (*A*), self-inflicted (*B*), unintentional (*C*), or undetermined (*D*) intent (Kaplan–Meier estimates). Graphs for mechanisms without mortality (probability of survival = 1) are not shown. Assault: cut/pierce versus firearm, $p = 0.03$; other struck versus firearm, $p < 0.001$; cut/pierce versus child abuse, $p = 0.01$; other struck versus child abuse, $p = 0.001$; other struck versus unspecified, $p < 0.001$; $p > 0.05$ for other combinations. Self-inflicted: firearm versus suffocation, $p > 0.05$. Unintentional: suffocation versus all other mechanisms, $p < 0.001$; firearm versus pedestrian, other, $p = 0.02$; firearm versus all other mechanisms, $p < 0.005$; firearm versus suffocation, $p < 0.001$. Undetermined: firearm versus unspecified, $p < 0.001$; suffocation versus unspecified, $p = 0.009$; firearm versus suffocation, $p > 0.05$.

Fig. 4.
Proposed matrix for depicting injury severity and resource utilization among different mechanisms of injury. Representative mechanisms of injury are shown.

Table 1

Cause of Death Among Children Dying of Each Mechanism

	Central Nervous System Injury	Hypoxia	Hypovolemia/Hemorrhage	Multiple Organ Failure	Other or Unknown
Type of Injury					
Blunt	838 (73.3)	96 (8.4)	66 (5.8)	50 (4.4)	92 (8.1)
Penetrating	52 (67.5)	4 (5.2)	13 (16.8)	1 (1.3)	7 (9.1)
Other	4 (30.7)	5 (38.4)	—	—	4 (30.7)
Intent of injury					
Assault	196 (76.8)	13 (5.1)	21 (8.2)	5 (2.0)	20 (7.8)
Self-inflicted	15 (51.7)	1 (3.4)	9 (31.0)	1 (3.4)	3 (10.3)
Undetermined	17 (73.9)	3 (13.0)	1 (4.3)	—	2 (8.7)
Unintentional	666 (72.0)	62 (6.7)	74 (8.0)	45 (4.9)	78 (8.4)
Mechanism of injury					
Cut/pierce	2 (50)	—	2 (50)	—	—
Fall					
Building	19 (82.6)	1 (4.3)	1 (4.3)	—	2 (8.7)
Furniture	4 (100)	—	—	—	—
Playground equipment	3 (100)	—	—	—	—
Stairs	5 (83.3)	—	—	—	1 (16.7)
Other falls from height	5 (55.6)	2 (22.2)	1 (11.1)	—	1 (11.1)
Falls on the same level	5 (71.4)	1 (14.3)	—	—	1 (14.3)
Other and unspecified	2 (66.7)	—	—	—	1 (33.4)
Firearm	46 (69.7)	3 (4.6)	9 (13.7)	1 (1.6)	7 (10.7)
Machinery	3 (75)	—	1 (25)	—	—
MV traffic					
Occupant	298 (76.1)	28 (7.2)	19 (4.9)	16 (4.1)	31 (7.9)
Motorcyclist	5 (62.5)	1 (12.5)	2 (25)	—	—
Pedal cyclist	50 (75.8)	3 (4.5)	5 (7.6)	3 (4.5)	5 (7.6)
Pedestrian	159 (73.6)	8 (3.7)	18 (8.3)	16 (7.4)	15 (6.9)
Other	2 (100)	—	—	—	—
Pedal cyclist, other	7 (87.5)	—	1 (12.5)	—	—

	Central Nervous System Injury	Hypoxia	Hypovolemia/Hemorrhage	Multiple Organ Failure	Other or Unknown
Pedestrian, other	33 (68.8)	3 (6.25)	1 (2.0)	4 (8.3)	7 (14.6)
Transport, other					
All-terrain vehicle	9 (60)	1 (6.7)	2 (13.4)	1 (6.7)	2 (13.3)
Other transport	8 (66.7)	—	1 (8.3)	1 (8.3)	2 (16.7)
Natural/environmental	11 (78.6)	1 (7.1)	2 (14.3)	—	—
Struck by, against					
Struck by falling object	7 (46.7)	5 (33.3)	1 (6.7)	1 (6.7)	1 (6.7)
Other struck	6 (54.5)	3 (27.3)	1 (9.1)	—	1 (9.1)
Suffocation	11 (29.0)	19 (50)	—	3 (7.9)	5 (13.2)
Other specified, classifiable					
Child abuse	179 (78.9)	18 (7.9)	8 (3.5)	5 (2.2)	17 (7.5)
Other	1 (9.1)	5 (45.5)	1 (9.1)	—	4 (36.4)
Other specified, not classifiable					
Unspecified	14 (70)	3 (15)	3 (15)	—	—
Total	894 (72.6)	105 (8.5)	79 (6.4)	51 (4.1)	103 (8.4)

* Percentage of deaths for each mechanism shown in parentheses.

Table 2
Type, Mechanism, and Intent of Injury and Hospital Mortality (%) Among Pediatric Trauma Patients

	Assault	Self-Inflicted	Unintentional	Undetermined	Total
Type of injury					
Blunt	11.0	29.1	4.6	2.4	2.9
Penetrating	6.5	52.0	18.9	1.3	2.6
Other/undetermined	16.7	—	0	14.6	14.4
Mechanism of injury					
Cut/pierce	2.2	0.0	0.2	0.0	0.3
Fall	—	—	—	—	—
Building	—	—	1.8	—	1.8
Furniture	—	—	0.2	—	0.2
Playground equipment	—	—	0.1	—	0.1
Stairs	—	—	0.5	—	0.5
Other falls from height	0.0	0.0	0.3	0.0	0.3
Falls on the same level	—	—	0.3	—	0.3
Other and unspecified	—	—	0.0	—	0.0
Firearm	8.8	72.2	10.1	50.0	12.4
Machinery	—	—	2.2	—	2.2
MV traffic					
Occupant	—	—	5.0	—	5.0
Motorcyclist	—	—	3.7	—	3.7
Pedal cyclist	—	—	4.2	—	4.2
Pedestrian	—	—	4.7	—	4.7
Other	—	—	2.1	—	2.1
Pedal cyclist, other	—	—	0.4	—	0.4
Pedestrian, other	—	—	5.3	—	5.3
Transport, other					
All-terrain vehicle	—	—	2.5	—	2.5
Other transport	—	—	1.6	—	1.6
Natural/environmental	—	—	1.3	—	1.3

	Assault	Self-Inflicted	Unintentional	Undetermined	Total
Struck by, against					
Struck by falling object	—	—	2.7	—	2.7
Other struck	0.4	—	0.6	—	0.6
Suffocation	0.0	51.6	35.0	33.3	38.8
Other specified, classifiable					
Child abuse	12.9	—	—	—	12.9
Other	0.0	0.0	2.0	0.0	1.9
Other specified, not classifiable	0.0	0.0	0.0	0.0	0.0
Unspecified	9.5	—	0.5	5.5	2.9
Total	10.3	36.3	2.3	6.8	2.9

Relationship Between Injury Severity and Resource Utilization and Mechanism of Injury

Table 3

	Emergency Department to Operating Room (%)	Any Operating Room (%)	No. ICU Days (mean $\pm$ SD)	No. Hospital Days (mean $\pm$ SD)	ISS 15 (%)	Died in Emergency Department (%)	Died in Operating Room (%)	Mortality (%)	Discharge to Rehabilitation Facility (%)
Type of injury									
Blunt	17.9	37.3	3.8 $\pm$ 6.6	1.0 $\pm$ 3.5	16.0	0.6	0.1	2.9	3.0
Penetrating	46.5	64.3	4.2 $\pm$ 6.6	0.9 $\pm$ 3.6	7.9	0.7	0.1	2.6	1.9
Other	22.2	34.4	4.4 $\pm$ 8.0	1.0 $\pm$ 3.5	16.0	6.7	0.0	14.4	3.9
Intent of injury									
Assault	11.1	25.6	2.0 $\pm$ 4.7	6.4 $\pm$ 8.9	38.7	0.9	0.2	10.3	5.1
Self-inflicted	12.5	23.8	2.0 $\pm$ 4.1	6.1 $\pm$ 11.1	36.8	8.8	0.0	36.3	13.7
Undetermined	12.5	32.6	1.9 $\pm$ 3.1	1.1 $\pm$ 5.8	25.9	1.3	0.3	6.0	3.6
Unintentional	20.4	40.1	0.9 $\pm$ 3.4	3.7 $\pm$ 6.4	13.9	0.6	0.1	2.3	2.8
Mechanism of injury									
Cut/pierce	55.0	75.0	0.4 $\pm$ 2.9	3.7 $\pm$ 5.3	3.3	0.2	0.0	0.3	0.9
Fall									
Building	9.3	21.8	0.9 $\pm$ 1.9	2.9 $\pm$ 3.8	16.7	0.3	0.0	1.8	2.5
Furniture	20.4	43.3	0.2 $\pm$ 1.0	1.8 $\pm$ 2.4	10.8	0.0	0.0	0.2	0.4
Playground equipment	39.9	68.6	0.1 $\pm$ 0.6	1.8 $\pm$ 2.4	2.8	0.0	0.0	0.1	0.1
Stairs	10.9	23.1	0.4 $\pm$ 1.5	2.0 $\pm$ 2.9	11.1	0.0	0.0	0.5	0.5
Other falls from height	18.3	34.7	0.5 $\pm$ 1.6	2.4 $\pm$ 3.9	14.0	0.0	0.0	0.3	0.8
Falls on the same level	27.3	56.8	0.2 $\pm$ 0.8	2.3 $\pm$ 3.2	4.9	0.0	0.0	0.3	0.4
Other and unspecified	25.7	51.6	0.2 $\pm$ 1.2	2.3 $\pm$ 3.5	6.3	0.0	0.0	0.1	0.4
Firearm	36.2	51.9	2.4 $\pm$ 5.5	6.8 $\pm$ 9.7	27.2	2.7	0.5	12.4	7.0
Machinery	50.8	67.0	1.3 $\pm$ 5.3	5.9 $\pm$ 9.8	12.6	0.0	0.0	2.2	3.5
MV traffic									
Occupant	11.3	27.8	1.7 $\pm$ 4.9	5.0 $\pm$ 8.5	21.9	1.0	0.1	5.0	5.8
Motorcyclist	27.2	43.3	1.1 $\pm$ 2.4	4.8 $\pm$ 5.3	17.0	0.9	0.9	3.7	3.3
Pedal cyclist	14.4	32.3	1.6 $\pm$ 4.4	5.4 $\pm$ 9.5	21.4	0.8	0.2	4.2	6.8
Pedestrian	12.1	31.1	1.6 $\pm$ 4.9	5.4 $\pm$ 9.0	19.1	1.4	0.2	4.7	6.5
Other	16.0	35.1	2.2 $\pm$ 5.7	5.5 $\pm$ 8.6	28.0	0.0	0.0	2.1	3.3

	Emergency Department to Operating Room (%)	Any Operating Room (%)	No. ICU Days (mean $\pm$ SD)	No. Hospital Days (mean $\pm$ SD)	ISS 15 (%)	Died in Emergency Department (%)	Died in Operating Room (%)	Mortality (%)	Discharge to Rehabilitation Facility (%)
Pedal cyclist, other	19.7	39.3	0.6 $\pm$ 1.9	3.0 $\pm$ 4.0	12.5	0.0	0.0	0.4	0.7
Pedestrian, other	13.6	27.0	1.4 $\pm$ 4.1	4.6 $\pm$ 7.2	18.6	2.5	0.0	5.3	2.7
Transport, other									
All-terrain vehicle	23.2	45.6	1.3 $\pm$ 3.6	4.9 $\pm$ 6.6	17.7	0.7	0.2	2.5	4.6
Other transport	24.4	42.0	1.0 $\pm$ 3.3	4.3 $\pm$ 6.3	17.3	0.4	0.1	1.6	3.2
Natural/environmental	33.8	50.9	0.7 $\pm$ 2.5	3.5 $\pm$ 6.6	7.0	0.3	0.0	1.3	1.2
Struck by, against									
Struck by falling object	22.0	43.2	1.0 $\pm$ 3.3	4.0 $\pm$ 5.7	13.8	0.9	0.0	2.7	2.6
Other struck	18.3	37.5	0.4 $\pm$ 1.3	3.0 $\pm$ 4.1	8.9	0.2	0.1	0.4	0.9
Suffocation	0.0	4.1	2.3 $\pm$ 4.3	4.1 $\pm$ 7.0	25.9	13.3	0.0	38.8	11.4
Other specified, classifiable									
Child abuse	6.8	20.9	2.4 $\pm$ 4.9	7.3 $\pm$ 9.5	48.4	0.9	0.2	12.9	5.1
Other	50.0	69.3	0.7 $\pm$ 2.9	3.4 $\pm$ 5.8	2.9	1.1	0.0	1.9	1.1
Other specified, not classifiable	23.3	42.8	0.5 $\pm$ 2.4	2.8 $\pm$ 4.8	4.5	0.0	0.0	0.0	1.3
Unspecified	20.7	48.0	0.6 $\pm$ 2.2	3.7 $\pm$ 5.3	14.2	0.1	0.1	2.4	1.8
Total	19.8	39.1	1.0 $\pm$ 3.5	3.8 $\pm$ 6.6	15.5	0.6	0.1	2.9	2.9

Table 4
Mechanisms of Injury Associated With the Highest Values for Each Resource or Outcome Measure

	Emergency Department to Operating Room	Any Operating Room Treatment	No. ICU Days	No. Hospital Days	ISS 15	Died in Emergency Department	Died in Operating Room	Mortality	Discharge to Rehabilitation Facility
Highest	Cut/pierce	Cut/pierce	Firearm	Child abuse	Child abuse	Suffocation	Motorcyclist-motor vehicle traffic crash	Suffocation	Suffocation
↑	Machinery	Fall from playground equipment	Child abuse	Firearm	Other motor vehicle traffic crash	Firearm	Firearm	Child abuse	Firearm
	Fall from playground equipment	Machinery	Suffocation	Machinery	Firearm	Pedestrian-not motor vehicle traffic crash	Pedestrian-motor vehicle traffic crash	Firearm	Pedal cyclist-motor vehicle traffic crash
	Firearm	Falls on the same level	Other motor vehicle traffic crash	Other motor vehicle traffic crash	Suffocation	Pedestrian-motor vehicle traffic crash	Child abuse	Pedestrian-not motor vehicle traffic crash	Pedestrian-motor vehicle traffic crash
Lowest	Natural/environmental	Firearm	Occupant-motor vehicle traffic crash	Pedal cyclist-motor vehicle traffic crash	Occupant-motor vehicle traffic crash	Occupant-motor vehicle traffic crash	Pedal cyclist-motor vehicle traffic crash	Occupant-motor vehicle traffic crash	Occupant-motor vehicle traffic crash