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Timing of mortality in pediatric trauma patients: A National Trauma Data Bank analysis☆,☆☆,★,★★

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ABSTRACT

Background/purpose: The classic "trimodal" distribution of death has been described in adult patients, but the timing of mortality in injured children is not well understood. The purpose of this study was to define the temporal distribution of mortality in pediatric trauma patients.
Methods: A retrospective cohort of patients with mortality from the National Trauma Data Bank (2007–2014) was analyzed. Categorical comparison of 'dead on arrival', 'death in the emergency department', and early (≤24 h) or late (>24 h) inpatient death was performed. Secondary analyses included mortality by pediatric age, predictors of early mortality, and late complication rates.
Results: Children (N = 5463 deaths) had earlier temporal distribution of death compared to adults (n = 104,225 deaths), with 51% of children dead on arrival or in ED compared to 44% of adults (p < 0.001). For patients surviving ED resuscitation, children and adolescents had a shorter median time to death than adults (1.2 d and 0.8 days versus 1.6 days, p < 0.001). Older age, penetrating mechanism, bradycardia, hypotension, tube thoracostomy, and thoracotomy were associated with early mortality in children.
Conclusions: Injured children have higher incidence of early mortality compared to adults. This suggests that injury prevention efforts and strategies for improving early resuscitation have potential to improve mortality after pediatric injury.
Level of evidence: Level III: Retrospective cohort study.

Trauma continues to be the leading cause of death and acquired disability in children and adolescents [1–8]. In the United States, 12,000 children die from injury each year [6]. The temporal nature of death in adult trauma patients has been extensively studied, beginning with Trunkey's adult cohort study which described a trimodal distribution of death after traumatic injury [9]. In this study, most patients died immediately after injury, with a second peak of mortality in the first few hours, and a third peak owing to late complications related to trauma (typically occurring more than one week after injury). Recent studies have challenged this trimodal concept, suggesting a shift in the temporality of trauma deaths largely from a decline in late mortality [10–17]. It is not known if these patterns are observed after pediatric injury. Although the overall principles of pediatric trauma care are similar to those for adult trauma care, important differences in mechanism of injury, anatomy, and physiology are observed between adults and children that lead to many differences in initial care [18]. Children have fewer or no comorbid conditions compared to adults, and are not as

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likely to succumb to long-term complications occurring after injury. Furthermore, adult trauma centers are more mature and numerous than pediatric trauma centers in the United States, and the incorporation of pediatric trauma centers into trauma systems may lead to differences in outcomes [19,20].

The purpose of this study was to investigate the temporal distribution of death after injury in children compared to adults. We hypothesized that the temporal distribution of mortality is different in pediatric and adult trauma patients, with a greater proportion of pediatric mortality in the "early" timeframe. We also performed secondary analyses to determine predictors of late mortality and prevalence of complications associated with late mortality.

1. Methods

1.1. Study design and patient selection

We performed a retrospective cohort study of patients treated at trauma centers in the United States from 2007 to 2014 using the American College of Surgeons National Trauma Data Bank® (NTDB®) Research Dataset (RDS). Patients were included in this study if they were less than 65 years old and had either an ED or inpatient discharge disposition code of died or expired. Patients were excluded if they sustained burn, drowning, hanging, or military injuries; or if they were transferred from a referral center. Patients were categorized as children (0–14 years) or adult (15–64 years) for the primary analysis and were further stratified for secondary analyses based on the Centers for Disease Control defined ranges (<1 year, 1–4 years, 5–9 years, 10–14 years, 15–24 years) [6].

1.2. Categorization of death and calculation of time to death

The primary outcome for this study was death by phase of care (dead on arrival [DOA], emergency department [ED], early inpatient [≤24 h], and late inpatient [>24 h]) for children compared to adults. Patients were categorized as dead on arrival, died in ED, or inpatient death based on the emergency department disposition and hospital discharge disposition variables (all years) as well as time of ED phase of care combined with death in ED (2007–2010 datasets) or absent signs of life on arrival variables (2011–2014 datasets). Specific combinations of disposition codes and categorization schema are tabulated in Appendix A. Total number of EMS minutes (EMSMINS), minutes in the ED (EDMIN), and length-of-stay minutes (LOSMIN) were used to calculate the total time to death for patients who survived ED resuscitation. Time was modeled in two ways: 1) dichotomized into early inpatient mortality (≤24 h) or late inpatient mortality (>24 h) for the primary outcome, and 2) treated as a continuous interval variable for survival analysis for the secondary outcome of inpatient time to death. Inpatient time was not calculated for patients who died on arrival or died in ED.

1.3. Predictors of early versus late mortality

To better understand risk factors for mortality, demographic and clinical variables potentially related to mortality were modeled, including: age, gender, race, ethnicity, insurance status, physiologic variables, mechanism of injury, severity of injury (using Abbreviated Injury Scales) and procedures within the first day of admission. Race was determined using the "RACE1" and "RACE2" variables, and a "multiracial" category was created to account for the reporting of more than 1 race per person. Primary payment method was classified into three groups: "no insurance" (self-pay, not billed, and other), "Medical/Medicaid" (Medicaid and Medicare), and "private insurance" (Blue Cross/Blue Shield, no fault automobile, worker's compensation, private/commercial insurance, and other government). Systolic blood pressure and heart rate were adjusted for age using normative values used in Pediatric Advanced Life Support (PALS) and transformed to dichotomous age-adjusted variables for hypotension, tachycardia, and bradycardia [21]. External cause of injury codes (ECODES) were used to classify whether a patient suffered a blunt or penetrating injury. The maximum Abbreviated Injury Score (AIS) was calculated for head and neck, face, thorax, abdomen, extremity, and external using predot codes and severity variables [22]. Specific procedures (endotracheal intubation, chest tube placement, transfusion, craniotomy, thoracotomy, and laparotomy) were identified by ICD-9 codes and included if they occurred within the first 24 h after injury.

1.4. Complications in late mortality patients

To assess for prevalence of complications in the late mortality subgroup, complication codes were used to identify specific complications including: acute respiratory distress syndrome, pneumonia, acute kidney failure/injury, deep venous thrombosis or pulmonary embolism (DVT/PE), decubitus ulcer, urinary tract infection, sepsis, catheter associated bloodstream infection, pulmonary thrombosis, and deep space surgical site infection (SSI). Owing to known variability in reporting of complications between centers and to decrease the impact of reporting bias, the analysis of complications was conducted on a subset of patients treated at trauma centers that have a history of reporting these complications to the database using previously described methodology [23].

1.5. Statistical analysis

Descriptive analyses were performed to report the frequency counts and percentages for categorical variables. Because all continuous variables were not normally distributed, the median and interquartile ranges were reported. A chi-square test or Fisher's exact test was used to determine if categorical variables differed between pediatric and adult groups, as well as between early and late mortality groups in pediatric trauma patients. The Wilcoxon–Mann–Whitney test was used to analyze the difference between early and late pediatric mortality groups for continuous variables. Inpatient mortality over time for patients surviving ED resuscitation was assessed with Kaplan–Meier survival plots and testing the equality over strata using the Kruskal–Wallis test, because no censored observations occurred. Odds ratios and 95% confidence intervals were reported for the logistic regression model looking at the outcome of early versus late mortality for pediatric trauma patients. Model covariates included age, gender, race, ethnicity, mechanism, AIS head and neck, AIS face, AIS chest, AIS abdomen, AIS extremity, AIS external, endotracheal intubation, chest tube placement, transfusion, craniotomy, thoracotomy, laparotomy, bradycardia, tachycardia, hypotension, and insurance payment. For variables that had 10% or more of the data missing (race, ethnicity, hypotension, and insurance payment), a "not specified" or "not reported" category was created to account for this group. Otherwise, patients with missing data on single variables were excluded from the multivariable analysis. Significance tests were two-tailed, with $\alpha = 0.05$. All analyses were performed using SAS software v. 9.4 (SAS Institute Inc).

2. Results

From 2007 to 2014, 5,836,507 patients were entered into the National Trauma Database. After excluding transfer patients, we identified 109,688 pediatric and adult patients that died (either on arrival, in the ED, or as inpatients). Pediatric patients had a lower proportion of male patients, higher rate of blunt trauma, greater frequency of head and neck injuries, lower rates of procedures, and a higher frequency of bradycardia (Table 1).

Mortality by categorical phase of care (on arrival, in ED, inpatient <24 h, and inpatient >24 h) differed between pediatric and adult patients, with a higher proportion of death on arrival and ED death for children compared to adults and a higher proportion of adults with inpatient deaths ($p < 0.01$; Fig. 1). A Kaplan–Meir survival plot of

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