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The epidemiology of inpatient pediatric trauma in United States hospitals 2000 to 2011☆

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ABSTRACT

Background: This study provides important updates to the epidemiology of pediatric trauma in the United States.
Methods: Age-specific epidemiologic analysis of the Healthcare Cost and Utilization Project's Nationwide Inpatient Sample, representing 2.4 million pediatric traumatic injury discharges in the US from 2000 to 2011. We present yearly data with overlying loess smoothing lines, proportions of common injuries and surgical procedures, and survey-adjusted logistic regression analysis.
Results: From 2000 to 2011 there was a 21.7% decline in US pediatric trauma injury inpatient discharges from 273.2 to 213.7 admissions per 100,000. Inpatient case-fatality decreased 5.5% from 1.26% (95% CI 1.05–1.47) to 1.19% (95% CI 1.01–1.38). Severe injuries accounted for 26.5% (se = 0.11) of all discharges in 2000 increasing to 31.3% (se = 0.13) in 2011. The most common injury mechanism across all age groups was motor vehicle crashes (MVCs), followed by assaults (15–19 years), sports (10–14), falls (5–9) and burns (<5). The total injury-related, inflation-adjusted cost was $21.7 billion, increasing 56% during the study period.
Conclusions: The overall rate of inpatient pediatric injury discharges across the United States has been declining. While injury severity is increasing in hospitalized patients, case-fatality rates are decreasing. MVCs remain a common source of all pediatric trauma.
Levels of evidence: Level III.

In the United States (US) trauma is the leading cause of death in children older than one [1]. Each year, one in four American children suffers an injury requiring urgent clinical care, leading to over 8.7 million hospital visits with an estimated annual treatment cost of $350 billion [1,2]. Recent estimates rank US death rates from pediatric trauma double those of the United Kingdom, Sweden, Italy, and several other developed nations [3], with unintentional trauma accounting for over 90% of pediatric trauma-related deaths [4].

Epidemiological analyses can help inform clinicians, researchers, and policy-makers about interventions, treatments, and control measures. Informed by clinical and population health studies, Sweden and Germany have reduced pediatric injury deaths by over 50% through the implementation of cost-effective prevention strategies such as expanded pre-school services and mandatory swim training [5]. While the US has certainly implemented its own prevention strategies [6], there is still more that can be done to reduce pediatric trauma.

A number of recent US epidemiologic studies have harnessed the power of large national registries [7–9] to explore the incidence and impact of traumatic injuries in pediatric populations [10–12]. Such efforts are typically restricted to specific injury types [13–15] or causes of pediatric trauma [16–18]. Studies that do investigate pediatric trauma more broadly largely obtain data from single institutions [19], single states [20], or by aggregating the data of other studies [21]. Additionally, the few that have indeed analyzed national trauma registries have included far fewer study years [22,23]. While these are informative, they do not comprehensively capture the broad and fluid nature of inpatient pediatric traumatic injury across the US. The most recent large-scale longitudinal overview of pediatric trauma was conducted at the state level and examined data from 1989 to 1999 [24].

In this study, we attempt to update the descriptive epidemiology of pediatric inpatient trauma care in the US. We construct a comprehensive population-based multi-year analysis of childhood trauma care across the US by analyzing data from the Healthcare Cost and Utilization Project (HCUP) Nationwide Inpatient Sample (NIS), a nationally-representative database for all pediatric traumatic injury hospital

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discharges between 2000 and 2011. In particular, we track recent trends in mechanisms of injury, severity of injury, cost of care, and the role of teaching hospitals and trauma centers in the treatment of those injuries. Using this extensive database, we aim to renew, and in some cases challenge, the existing understanding of the scope of inpatient pediatric injuries and the best methods to improve outcomes.

1. Methods

1.1. Data sources and designs

Data were obtained from the US Agency for Healthcare Research and Quality (AHRQ) HCUP NIS for years 2000–2011. The NIS is a 20% weighted sample of the HCUP State Inpatient Database, itself a census of all hospital discharges in a state. It is representative of all US community hospitals (non-federal, general, and specialty hospitals, including public hospitals and academic medical centers). A complete census of discharges for each sampled hospital is included in the database. To obtain accurate estimates, analyses must account for complex survey methods by applying weights and adjusting for clustering.

Survey-adjusted point estimates and standard errors for individual years were verified against estimates obtained from a publicly available HCUP online query system [25]. Inclusion criteria were patients 0 to 19 years old discharged with primary diagnoses of traumatic injury. Although the American College of Surgeons Committee on Trauma uses an age cut-off of 15 to define “pediatric” [26], we chose an age cut-off of twenty to allow for comparisons with the older teenage sub-group. Traumatic injury discharges were identified using principle or first-listed ICD 9th edition [27] diagnosis codes for acute injury 800–904.9, 909.4, 909.9, 910–994.9, 995.5–995.59, and 995.80–995.85. As noted in the HCUP documentation, the ICD-9-CM coding guidelines define principal diagnosis as “that condition established after study to be chiefly responsible for occasioning the admission of the patient to the hospital for care” [28]. Discharge codes for “late effect” primary diagnoses (ICD 905.0–909.9), insect bites (910.4, 910.5, 911.4, 911.5, 912.4, 912.5, 913.4, 913.5, 914.4, 914.5, 915.4, 915.5, 916.4, 916.5, 917.4, 917.5, 919.4, 919.5), poisonings (960.0–964.9, 965.00–965.02, 965.09, 965.1, 965.4, 965.5, 965.61, 965.69, 965.7–969.0, 969.00–969.09, 969.70–969.73, 969.1–969.7, 967.0–967.9, 969.79, 969.8–980.9, 970.81, 970.89, 981, 982.0–985.9, 986, 987.0–989.7, 989.81:989.89, 989.9, 990, 991.0–995.2, 995.20–995.29, 995.3, 995.4), anaphylaxis (995.60–995.69,995.7), and additional miscellaneous diagnoses (e.g. malignant hyperthermia, systemic inflammatory response syndrome, malfunctioning cardiac devices, 995.86–996.00) were removed.

Injury severity was quantified using the ICD-derived Injury Severity Score (ICISS) [29] and categorized as severe vs. non-severe. ICISS scores are defined as the probability of patients surviving their injuries (from 0 to 1) and are calculated in two steps. First, survival risk ratios (SRRs) for each injury diagnosis in a data set are “...calculated as the ratio of the number of times a given ICD-9 code occurs (in surviving patients) to the total number of occurrences of that code.” Second, the ICISS for an individual patient is calculated as "the product of all the survival risk ratios for each of an individual patient's injuries” [30]. An ICISS cut-off of less than 0.94 was used to categorize patients with the most severe injuries [31]. This identifies patients with a 6% or greater probability of dying, and has performed well in previous analyses, returning an odds ratio of 6.75 (95% CI 6.48, 7.03) in a multivariate logistic regression analysis of trauma mortality [32]. Other prevalent scoring tools such as the IPPS [33], ISS [34], and TRISS [35] were not applicable given dataset constraints.

To control for non-traumatic injury diagnoses, a Charlson comorbidity index (CCI) score [36] was calculated. Because of the very high proportion of patients without CCI conditions, the score variable was heavily skewed and so was categorized into an indicator variable for patients with a CCI greater than 2. Primary ICD-9 codes were categorized according to the Barell matrix, an injury diagnosis matrix tool used to standardize the classification of ICD-9 injury codes according to 12 nature-of-injury columns and 36 body-location rows [37,38]. We used the HCUP Clinical Classification Software system to categorize procedure codes.

Because NIS does not contain an explicit variable for trauma center designation, data on 2040 US trauma centers were obtained from the American Trauma Society (ATS) website [39,40]. Data were then matched by name and address to 3706 HCUP-sampled US hospitals in the study data set, yielding 1038 hospitals present in both ATS and NIS. The hospitals were assigned trauma center level designations 1 to 5 as reported by the ATS, but were not classified by pediatric trauma center designation. Hospitals that did not match were assumed to be non-trauma centers. Notably, 1,573,134 (se = 73,824) or approximately 65.7% of hospital discharges were missing sufficient information to code trauma center status.

Teaching hospitals were identified by an NIS variable. Costs were based on hospital-submitted charges for each discharge. These charges were converted to costs with the AHRQ HCUP cost-to-charge ratio files using the group weighted average cost-to-charge ratio variable. Costs were then adjusted for inflation and standardized to 2010 US dollars based on the all-item average yearly consumer price index obtained from the Bureau of Labor Statistics [41].

1.2. Analyses

Statistical analysis consisted of survey-adjusted counts, proportions, means, standard errors, and 95% confidence intervals. Annual rates were calculated using US census data obtained from the AHRQ as part of the HCUP family of data products. We analyzed yearly data with overlying loess smoothing lines (locally weighted polynomial regression) and assessed strength and statistical significance of the beta coefficient for bivariate linear association between year and annual incidence rates. We conducted a survey-adjusted logistic regression analysis for the effect of year on the odds of in-hospital death with control variables for age, gender, weekday vs. weekend admission, injury severity, trauma-center status, teaching-hospital status, and Charlson index score. This was done to track changes in trauma outcomes over time not explained by changes in hospital admissions patterns. We used the R “survey” package [42] to adjust for the complex sampling design of NIS and conduct analyses, and we tested for the assumption of linearity of the year variable and controlled for year-to-year variability in the survey results using an approach recommended by the Centers for Disease Control and Prevention [43,44]. Trends in certain variables over time—including injury incidence and mortality—were assessed by aggregating and comparing data from the first half of the study period (2000–2005) to the second half (2006–2011). This method was preferable to regression analysis as there were relatively few data points, making the results less susceptible to annual variance than they would have been had we, for example, compared data from the first and last years of the study. A complete set of notes and code to reproduce or adapt our methods are available upon request.

2. Results

Between 2000 and 2011 there were 2,395,402 (se = 104,728) inpatient traumatic injury admissions in the US for children and teenagers aged 0 to 19. The proportion of female admissions was 31.7% (sd = 0.2%). There was a 21.7% decline in the mean annual rate of inpatient traumatic injury admissions from the first 6 years of the study compared to the second 6 years, from 273.2 admissions per 100,000 population to 213.7. There was no significant interaction between US region and year. The mean age of a child discharged for a traumatic injury remained constant at 11.2 years (se = 0.12) throughout the study period. In total, there were 29,662 (se = 1998) inpatient deaths because of traumatic injury for an overall inpatient case-fatality rate of 1.24% (se = 0.04).