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Research article

Differences in Incidence and Case Fatality of Abusive Head Trauma

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ABSTRACT

Background: Abusive head trauma (AHT) in children older than 1 and younger than 5 years old is thought uncommon and rarely studied.
Objective: This study estimates national incidence and case fatality rate of abusive head trauma (AHT), and evaluates differences by age, sex, race, and region, with a focus on children of 2-4 years.
Participants and setting: Hospital discharges were extracted from The Healthcare Cost and Utilization Project's Kids' Inpatient Database from 2000, 2003, 2006, 2009, and 2012 using the CDC's narrow definition of AHT.
Methods: Survey-weighted chi-square tests were used to assess differences in incidence and case fatality rates.
Results: The average annual incidence per 100,000 children was highest in < 1 year-olds (27), followed by age 1 (4), age 2 (3), and age 3-4 (1). Average annual incidence varied significantly by sex ($p = 0.0001$), race ($p < 0.0001$), and region ($p = 0.0002$) within each age category. The average annual case fatality rate increased significantly with age, with a rate of 0.10 among children age < 1 year, 0.15 for age 1, 0.23 for age 2, and 0.20 for age 3-4 years. The average annual case fatality rate was higher in the South (0.12) than West (0.10), Midwest (0.09), and Northeast (0.08) among children < 1 year of age.
Conclusions: Black and Hispanic children and hospitals in the Midwest experienced higher incidence of AHT than White children and Northeast hospitals, respectively, especially in cases < 1 year of age. Case fatality rates increased significantly with age, and the South experienced the highest rates for infants < 1 year.

1. INTRODUCTION

Abusive head trauma (AHT) primarily occurs in children < 5 years old, with the highest incidence reported among < 1 year olds (14.0-33.4 per 100,000) in studies of populations worldwide, including in the US.[1–6] AHT is the leading cause of death from physical abuse in children < 5 years of age[7] with 11%-36% mortality.[1,2,8] Prevention efforts focus on children at the greatest risk of AHT (< 1

Abbreviations: AHT, Abusive Head Trauma; ICD-9-CM, International Classification of Disease, Ninth Revision, Clinical Modification; CI, Confidence Interval; KID, Kids' Inpatient Database

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year), however, evidence suggests that nearly 20% of AHT cases in the US involve children age 1-4 years.[9–11]

Even though AHT disproportionately affects children < 1 year old, there remain significant knowledge gaps regarding the effect of AHT in children 1-4 years, and age-related case fatality in the United States. Estimates of AHT incidence rarely include children older than 2 years. The most recent incidence estimates were described for Western New York[12] and West Virginia[13] in children < 24 months of age. Earlier, nationally representative reports of incidence were specific to children < 2 years of age as well.[4,6,14,15] Estimates of AHT case fatality for children < 5 years old have been described,[7,16] however, these studies used a broad case definition with a lower specificity than the Center for Disease Control and Prevention's (CDC) narrow definition. There is limited data on risk factors (age, sex, race, geographical region) associated with AHT incidence and fatality. This study aims to expand knowledge of AHT incidence in children < 5 years old in the United States and investigate factors associated with incidence and case fatality, particularly age.

Children < 1 year old are at significant risk of developing AHT from being shaken due to their relatively large and heavy head, weak neck muscles, and small body size. Older toddlers experience different, more severe types of injuries that often involve blunt impacts consistent with being thrown or struck in the head,[17–21] though a small case series described shaking as the mechanism of injury for a few older toddlers with AHT.[22]

Understanding morbidity and mortality associated with AHT in children < 5 years old is vital for several reasons. First, it is crucial to recognize that while children < 1 year old have the highest incidence of AHT, children older than 1 year represent a sizeable fraction of children who experience these injuries. Second, failure to recognize AHT in children 1-4 years old may contribute to delays in diagnosis and higher mortality.[10] Timely and accurate diagnosis of AHT is particularly critical among children older than 1 year as evidence suggests a significantly higher risk of mortality in this population.[9,10]

In this study, we used the Kids' Inpatient Database (KID) to estimate incidence and case fatality of AHT in children < 5 years old and evaluated differences in these rates by age, sex, race, and geographic region. We hypothesized that differences in incidence and case fatality will be evident when stratified by these factors. Specifically, we expected case fatality to be higher in children older than 1 year.

2. Methods

2.1. Study Design and Data Source

We used the administrative hospital discharge data from the Kids' Inpatient Database (KID) of the Healthcare Cost and Utilization Project (HCUP) for this study. The KID, which is available every three years, is assembled from a two-stage cluster sample of 10% of all healthy newborns and 80% of all other pediatric discharges reported by participating hospitals. Hospital participation has increased from 2,784 community hospitals across 27 states in 2000 to 4,100 community hospitals across 44 states in 2012. KID allows the study of a child's hospital encounter by capturing factors such as type of admission, diagnostic codes, procedure codes, mortality, length of stay, and complications. It does not capture a patient's health or treatment before or after a single hospital encounter. Available hospital attributes include children's hospital designation, number of beds, geographic region, and location.

2.2. Patient Selection and Definition of AHT

Hospital encounters of children < 5 years old in 2000, 2003, 2006, 2009, and 2012 were classified as AHT cases based on the Centers for Disease Control and Prevention (CDC) algorithms for IDC-9-CM codes with additional E-codes. This study population includes cases across 706 unique hospitals in 44 states. AHT was defined according to the CDC definition of injury to the skull or intracranial contents of an infant or young child (< 5 years of age) due to inflicted blunt impact and/or violent shaking.[23] For injury surveillance and research, the CDC proposed two definitions for analysis of data from International Classification of Diseases (ICD) codes. The narrow definition of "definite or presumptive" AHT requires the combination of one of the listed ICD-9-CM injury codes with an assault-related "external cause" (E) code, an abuse code, or the code for shaken baby syndrome. The broad definition uses a more comprehensive set of injury codes and does not require an external code.[23] We employed the narrow definition in this study since it captures definite or presumptive AHT with higher specificity. A detailed description of the codes utilized to capture the study population is provided in Supplementary Table 1. Data and methods for this study were approved by expedited review by the University of California Davis Institutional Review Board (IRB).

2.3. Children and Hospital Factors

We captured age in years at case definition of AHT in four non-overlapping groups. Cases from 0 to 11 months old were categorized as age 0; 12 to 23 months as age 1; 24 to 35 months as age 2; and 36 to 59 months as age 3-4 given the smaller sample size of older children. Race in HCUP is uniformly coded into broad categories of White, Black, Hispanic, Asian or Pacific Islander, Native American, and Other, which is voluntarily self-reported by the patients.[24] Asian or Pacific Islander and Native Americans represented only a small portion of the sample and so were collapsed into the Other race category for analysis. Hospital regions include Northeast, Midwest, South, and West. The states included in each region are listed in Supplementary Table 2.

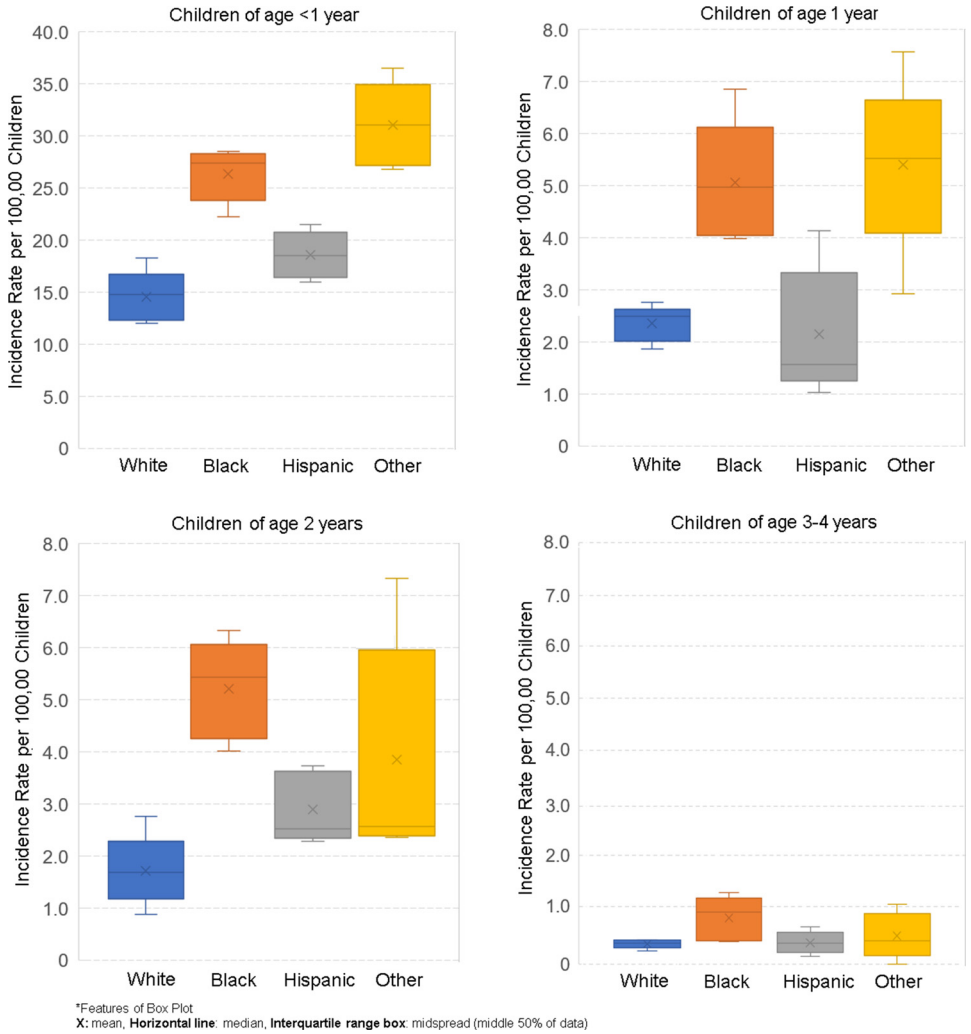

Fig. 1. Box and whisker plots of annual incidence by race stratified by age over study period (2000, 2003, 2006, 2009, and 2012).

2.4. Statistical Analysis

Survey weights were incorporated at all levels of analysis to calculate national estimates. The incidence of AHT was calculated for each year by dividing the number of identified AHT cases by the number of children within each age group in the same year as obtained from bridged race population estimates from the National Center for Health Statistics.[25] Case fatality rates were calculated within-strata as the ratio of fatal pediatric AHT cases to all pediatric AHT cases for each year. Survey-weighted chi-square tests were used to assess differences in incidence and case fatality rates by age, sex, race, and region. We used box plots to visualize the variability and differences in incidence and case fatality across race and region for individuals group according to age of case definition for 2000, 2003, 2006, 2009, and 2012 (Figs. 1–3). Statistical tests were two-sided with significance defined as p-values < 0.05. Statistical analysis was performed using R version 3.5.2 ("Eggshell Igloo", R Core Team 2018).

3. Results

3.1. Overall Incidence

We identified 7,264 children of < 5 years of age with AHT in 2000, 2003, 2006, 2009, and 2012. The average annual incidence was 7.48 cases per 100,000 children age < 5 (Table 1, footnote). The average annual incidence was significantly higher among males than females (8.66 vs. 5.96, $p < 0.0001$). Black children (7.68) had higher average annual incidence than Hispanics (5.03) and Whites (3.65). The Midwest region reported higher average annual incidence (9.64) than the West (7.26), South (6.99), and Northeast (5.30) regions.

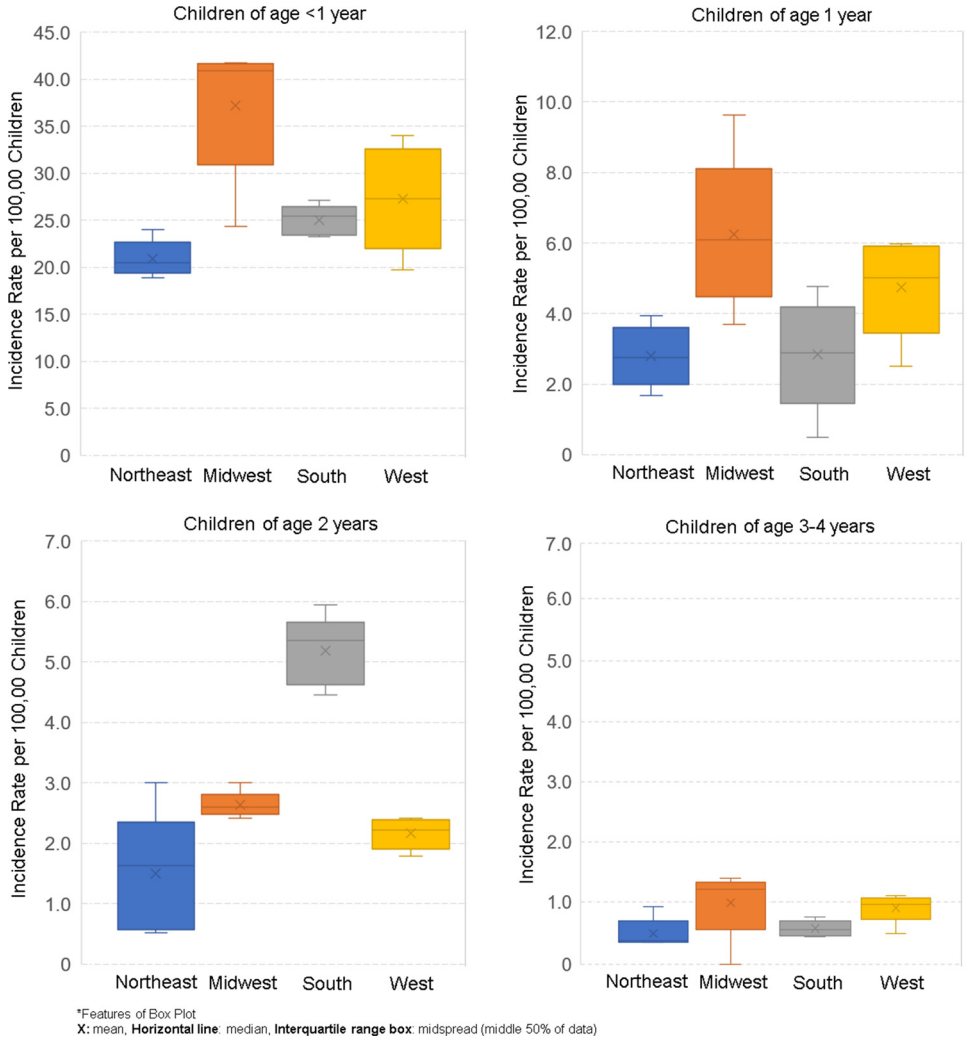

Fig. 2. Box and whisker plots of annual incidence by region stratified by age over study period (2000, 2003, 2006, 2009, and 2012).

3.2. Incidence by Age, Sex, Race, and Region

The average annual incidence of children < 1 year was 27.46, compared to 4.44 in 1 year-olds, 3.27 in 2 year-olds, and 0.71 in 3-4 year-olds. Among < 1 year-olds, Blacks experienced higher average annual incidence than Hispanics and Whites (26.32, 18.57, and 14.56, respectively; $p < 0.0001$) (Fig. 1); Other races (which includes Asian or Pacific Islander, Native American, and unspecified) experienced an average annual incidence of 31.06. Differences by race among 1 and 2 year-olds were similar to children < 1 year ($p = 0.001$ and $p < 0.0001$, respectively), although the scale of the differences in incidence among these age groups were significantly smaller than children < 1 year. Trends in the incidence of AHT by race in 3-4 year-olds is noticeably different from that of children younger than 3 (Fig. 1). Males experienced higher incidence than females in all age groups (Table 2). The highest difference in the average annual incidence by sex was observed in 0 year-olds (33.38 versus 21.31, $p < 0.0001$, Table 2 footnote). The average annual incidence of AHT was consistently higher in the Midwest region for children of all age groups, with the exception of higher incidence in the South for 2 year-olds (Fig. 2).

3.3. Overall Case Fatality

The case fatality rate remained constant throughout the study period; in 2000, the estimated case fatality was 0.11 (95% CI: 0.08-0.14) and in 2012 it was 0.12 (95% CI: 0.10-0.14) (Table 3). For each year of the study, case fatality rates for at least one category of older children were significantly higher than the rate of children < 1 year. Some strata had a rate nearly 3 times that of children < 1 year; in 2003 for example, 3-4 year-olds had a case fatality rate of 0.31 (95% CI: 0.18-0.49) while children < 1 year had a rate of 0.10 (95% CI: 0.08-0.12). Large differences were not necessarily consistent across years within specific age categories, as in 2012 where the case fatality rate for 3-4 year-olds (0.13, 95% CI: 0.06- 0.27) did not differ significantly from children < 1 year (0.09, 95% CI:

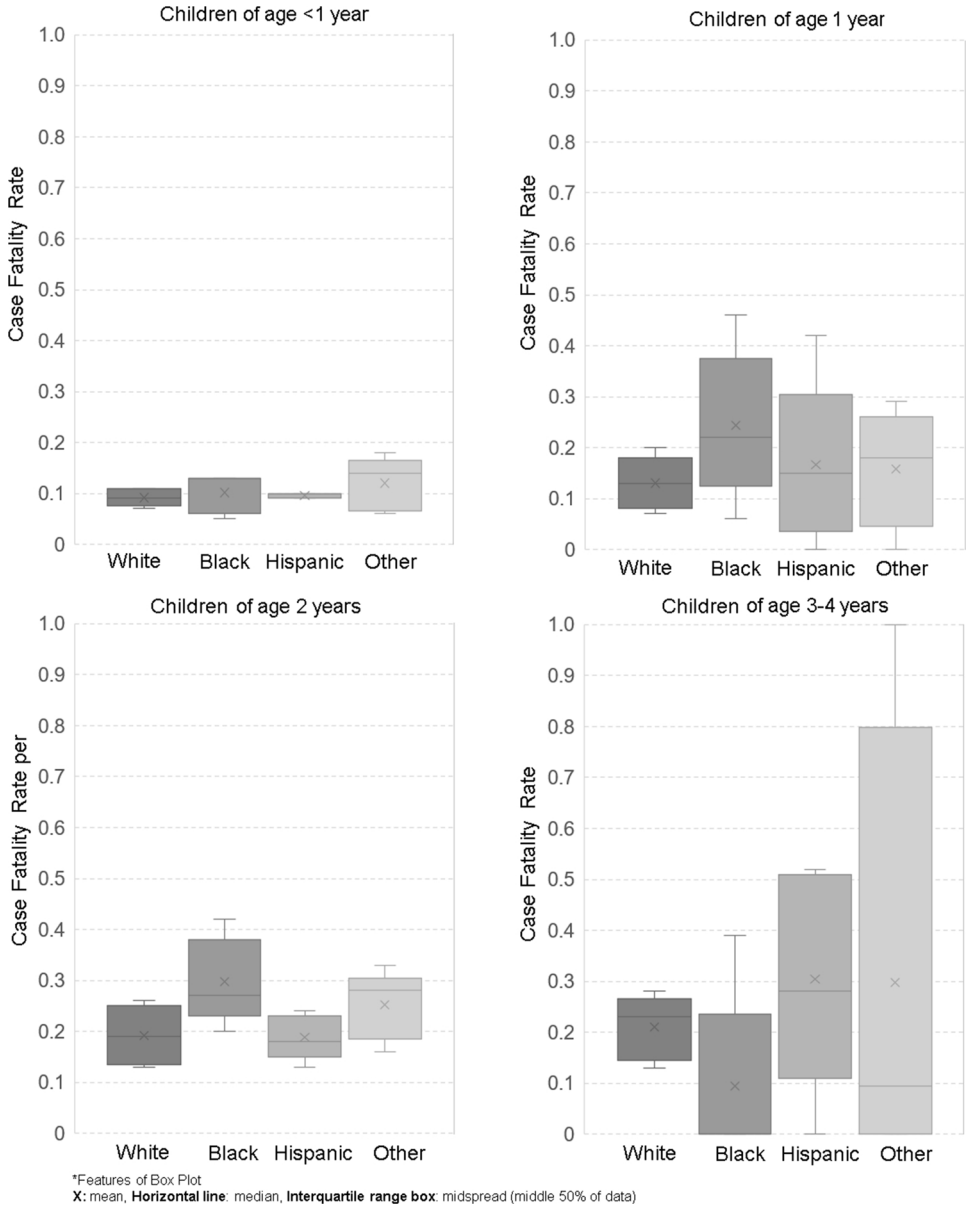

Fig. 3. Box and whisker plots of annual case fatality rate by race stratified by age over study period (2000, 2003, 2006, 2009, and 2012).

0.07-0.12).

3.4. Case Fatality by Age, Sex, Race, and Region

The average annual case fatality rate was similar among males (0.12) and females (0.13) (Table 4). The average annual case fatality rate was higher in 2 year-olds compared to children < 1 year for both males (0.10 versus 0.24) and females (0.10 versus 0.21). Estimates of the average annual case fatality rates among < 1 year-olds were comparable across the various race categories (Fig. 3). In 2 year-olds and particularly among 3-4 year olds, there was a trend toward higher average annual case fatality rates in Blacks and Hispanics, but some age/race strata were too small to draw solid conclusions from. The average annual case fatality rate was higher in the South (0.12) than West (0.10), Midwest (0.09), and Northeast (0.08) among children < 1 year of age (Fig. 4). Children age 2 and 3-4 in the Midwest seemed to experience higher case fatality rates than other regions.

4. Discussion

The findings presented in this study vary in magnitude from prior studies of incidence and case fatality of AHT because it utilized

Table 1
Incidence per 100,000 children age < 5 years and 95% confidence intervals.

	Year of Hospital Discharge				
Variables	2000	2003	2006	2009	2012
All Cases	7.97 (6.57, 7.87)	7.74 (7.23, 8.25)	7.71 (7.21, 8.22)	7.33 (6.87, 7.79)	6.63 (6.20, 7.05)
Sex					
Male	8.31 (7.34, 9.28)	9.13 (8.52, 9.91)	9.21 (8.44, 9.98)	8.87 (8.17, 9.58)	7.77 (7.12, 8.41)
Female	6.09 (5.23, 6.94)	6.43 (5.76, 7.11)	6.15 (5.50, 6.80)	5.71 (5.13, 6.29)	5.42 (4.87, 5.97)
Race					
White	3.68 (3.11, 4.26)	3.30 (2.91, 3.68)	3.43 (3.04,3.82)	3.43 (3.04,3.82)	3.88 (3.51, 4.25)
Black	7.84 (6.35, 9.32)	7.77 (6.46, 9.07)	7.33 (6.10, 8.57)	8.05 (6.87, 9.23)	7.39 (6.29, 8.49)
Hispanic	6.26 (5.07, 7.45)	5.59 (4.65, 6.54)	4.57 (3.77,5.37)	4.50 (3.78, 5.22)	4.25 (3.58, 4.93)
Other	8.50 (5.59, 11.42)	9.01 (6.82, 11.20)	9.13 (7.05, 11.20)	7.55 (5.87, 9.23)	7.21 (5.66, 8.77)
Region					
Northeast	5.33 (4.32, 6.35)	4.81 (3.81, 5.81)	5.24 (4.15, 6.33)	5.97 (4.96, 6.98)	5.16 (4.23, 6.08)
Midwest	6.77 (4.81, 8.74)	10.54 (9.28, 11.81)	11.19 (9.90, 12.47)	10.17 (9.00, 11.34)	9.55 (8.45, 10.65)
South	7.40 (6.49, 8.31)	7.12 (6.28, 7.95)	6.99 (6.21, 7.78)	6.96 (6.22, 7.70)	6.47 (5.78, 7.17)
West	8.79 (7.59, 10.00)	8.47 (7.39, 9.55)	7.38 (6.40, 8.36)	6.33 (5.47, 7.18)	5.31 (4.56, 6.07)

Average incidence over study period: All cases (7.48), Male (8.66), Female (5.96), White (3.54), Black (7.68), Hispanic (5.03), Other (8.28), Northeast (5.30), Midwest (9.64), South (6.99), and West (7.26).

Table 2
AHT incidence per 100,000 children by year for males and females.

	Male, Female				
	2000	2003	2006	2009	2012
All	8.32, 6.09	9.13, 6.43	9.21, 6.15	8.87, 5.71	7.77, 5.42
Age in years					
0	31.38, 22.72	36.13, 22.15	34.74, 20.25	34.76, 21.78	29.89, 19.67
1	4.55, 4.20	4.61, 4.29	6.04, 5.03	4.41, 3.44	4.07, 3.82
2	4.15, 2.98	2.37, 4.10	2.95, 3.62	4.07, 2.43	3.36, 2.69
3-4	0.68, 0.24	0.96, 0.61	0.94, 0.80	0.73, 0.53	0.96, 0.63

Average incidence over study period by age, 0: 27.46; 1: 4.44; 2: 3.27; 3-4: 0.71.
Male (8.66), Female (5.96). By Age, 0: Male (33.38), Female (21.31); 1: Male (4.74), Female (4.16); 2: Male (3.38), Female (3.16); 3-4: Male (0.85), Female (0.53).

Table 3
Case fatality rate, 95% confidence intervals, and p values.

	Year of Diagnosis				
	2000	2003	2006	2009	2012
Overall	0.11 (0.08, 0.14)	0.12 (0.10, 0.14)	0.14 (0.12, 0.17)	0.13 (0.11, 0.15)	0.12 (0.10, 0.14)
Age in years					
0	0.09 (0.07, 0.12)	0.10 (0.08, 0.12)	0.12 (0.10, 0.15)	0.10 (0.08, 0.12)	0.09 (0.07, 0.12)
1	0.10 (0.03, 0.26)	0.15 (0.09, 0.23)	0.19 (0.13, 0.27)	0.16 (0.10, 0.25)	0.17 (0.11, 0.25)
2	0.26 (0.15, 0.41)	0.21 (0.13, 0.32)	0.18 (0.10, 0.28)	0.25 (0.17, 0.35)	0.23 (0.15, 0.33)
3-4	0.10 (0.02, 0.38)	0.31 (0.18, 0.49)	0.19 (0.09, 0.34)	0.27 (0.14, 0.45)	0.13 (0.06, 0.27)
p-value	0.0062	< 0.0001	0.0364	< 0.0001	0.0005

Average case fatality over study period (0.12). By Age, 0: 0.10; 1: 0.15; 2: 0.23; 3-4: 0.20.

the CDC's narrow case definition to capture both fatal and non-fatal AHT hospitalizations in children < 5 years old from the KID database through 2012. Similar to previous studies, the highest incidence of AHT was among children under 1 year old, with an average annual incidence of 27.46 per 100,000 children over the study period of 2000, 2003, 2006, 2009, and 2012. We documented an average incidence of 4.44 in 1 year-olds, 3.27 in 2 year-olds, and 0.71 in 3-4 year-olds. We showed a noticeable variation in incidence by race, sex, and geographical region across different age categories and these findings were consistent with previous studies, particularly for children < 1 year. These findings represent the most updated and specific documentation of AHT case fatality in a population that investigated incidence variation across age, sex, race, and geographical region.

Table 4
Case fatality rate by year and sex, and 95% confidence intervals.

	Male, Female				
	2000	2003	2006	2009	2012
All	0.09, 0.13	0.12, 0.12	0.14, 0.15	0.12, 0.14	0.11, 0.12
Age in years					
0	0.08, 0.10	0.10, 0.09	0.12, 0.13	0.10, 0.11	0.09, 0.09
1	0.07, 0.13	0.19, 0.10	0.16, 0.24	0.13, 0.20	0.09, 0.26
2	0.21, 0.33	0.23, 0.20	0.20, 0.16	0.27, 0.22	0.28, 0.16
3-4	0.08, 0.16	0,0	0.21, 0.16	0.26, 0.29	0.11, 0.17

Average case fatality over study period: Male (0.12), Female (0.13). By Age, 0: Male (0.10), Female (0.10); 1: Male (0.13), Female (0.19); 2: Male (0.24), Female (0.21); 3-4: Male (0.13), Female (0.16).

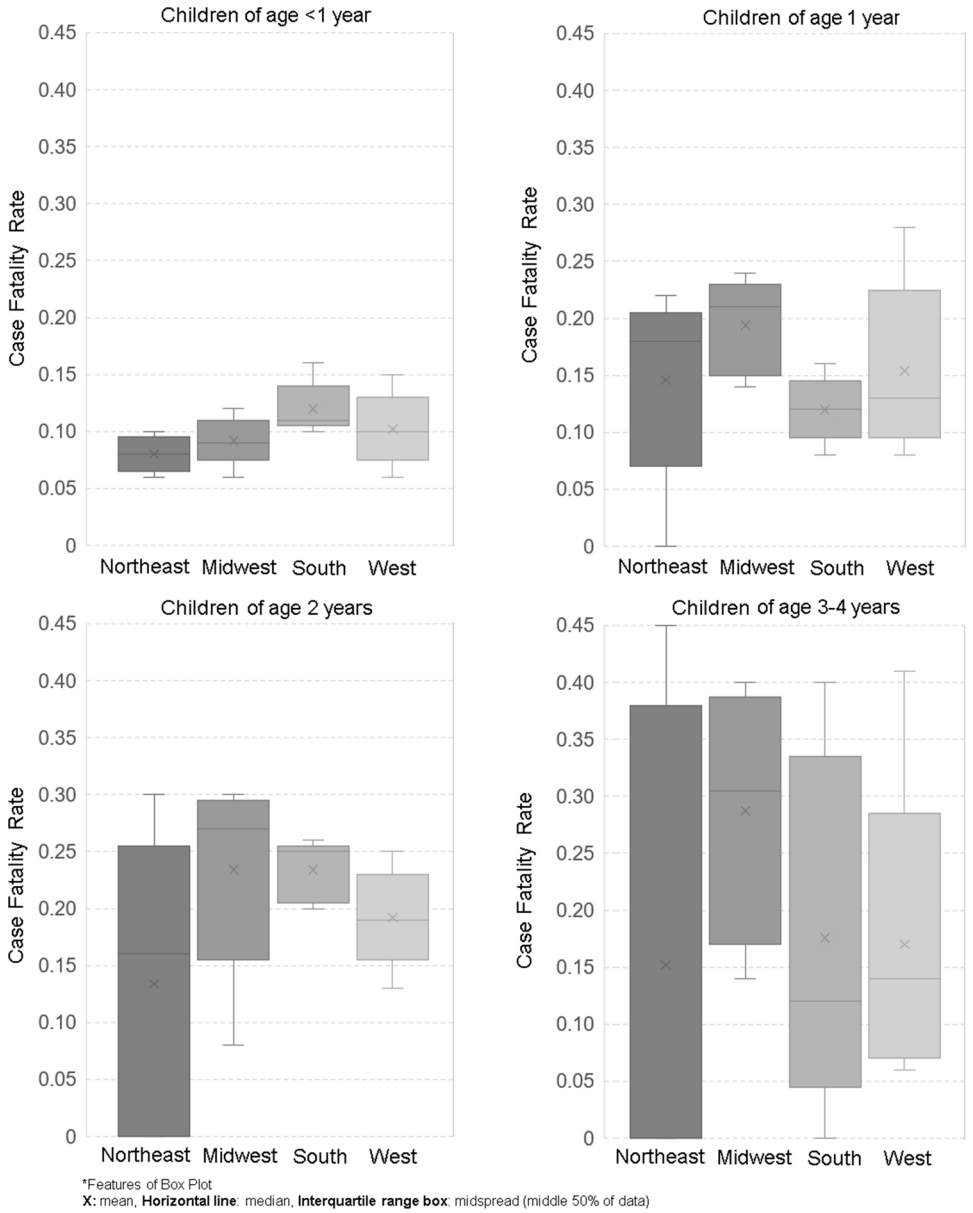

Fig. 4. Box and whisker plots of annual case fatality rate by region stratified by age over study period (2000, 2003, 2006, 2009, and 2012).

4.1. Differences in Incidence of AHT

The overall incidence of AHT in children age < 5 years old was 7.5 per 100,000 population and is consistent with the rate of 7.8 per 100,000 children age < 5 years old estimated using the narrow definition and the Nationwide Inpatient Sample (NIS) in a study capturing data from 2003-2008.[5] The average annual incidence of AHT was 27.5 per 100,000 in 0 year-olds and only 8.4 per 100,000 when combining children age 1-4 years. Shanahan et al. (2013), Parks et al. (2012), and Niederkrotenthaler et al. (2013) documented incidence estimates of 33.4, 32.2, and 39.8 per 100,000 children age < 1 year, respectively, however, only the first estimate represents AHT cases based on the narrow definition.[5,6,14] The slight differences in incidence estimates from these studies can be partially described by variation in case definition for AHT (narrow versus broad), different datasets being utilized to extract these estimates (KID versus NIS), as well as differences in the assumed denominator for incidence estimates (bridged US census data versus total cases of study population). An incidence of 29.7 among children < 1 year was estimated from a large population in North Carolina.[4]

Our study observed clear trends of higher incidence among non-White children when compared to Whites, in particular among cases of children under < 3 years of age. These findings are consistent with previous state-level and national estimates of study populations involving children < 2 years.[6,14] Similar differences in the rates of substantiated child maltreatment in the US have also been documented,[31] with 25.2 substantiated maltreatment cases per 1,000 Black children, compared to 12.6 cases per 1,000 Hispanic children and 10.6 cases per 1,000 White children. There was a slightly higher incidence in Black children of age < 1, age 1-2, and age 3-4 years than other races. Poverty is a likely driver for this trend; in 2012 Black households were disproportionally affected by poverty.[26] It is not clear whether non-White children are truly abused more often, if minority families are more likely to be reported for abuse, or if reports of maltreatment among minority children are more likely to be substantiated.[32] It is possible that implicit biases in the diagnosis of definite AHT makes this trend of increased incidence in Non-Whites inaccurate.

Males < 1 year old were significantly more likely to experience AHT than females of similar age (average incidence 33.4 vs. 21.3 per 100,000 children). Our study illustrates that while males continue to exhibit a higher incidence of AHT than females beyond the age of 1 year, the magnitude of this difference is dampened with age. There are limited data about factors that contribute to the differential risk of AHT in boys and girls. During infancy, males are more likely than females to fuss, cry, show negative facial expressions such as anger, and to want to be picked up by their mothers.[27–29] Female infants seem less vulnerable to interactive stresses, and these gender differences in emotional expressivity and self-regulation seemed to differentially affect the regulatory demands of mothers and sons versus mothers and daughters.[30] More recently, Tronick et al. (2007) noted that 6-month old males were more emotionally reactive than same-age females during face-to-face social interactions with their mothers.[27] Boys with developmental challenges require comprehensive support, yet they often receive poor quality care given that they are more difficult to look after. Biological and social constraints work against positive health outcomes for young males[31] and consequences may be more apparent during infancy than toddler age where differences in maturity and communication may be less apparent.

Regional variation in annual incidence was significant in all age groups in this study, with highest rates in the Midwest and lowest in the Northeast regions. This variation was largest in children < 2 years old. In contrast, among 2 year-olds, the South had the highest average annual incidence at 5.18 per 100,000 children. Previous studies described regional differences in incidence among children younger than 2 years.[6] The lower incidence in the Northeast may be partially due to the success of AHT prevention programs in regions of New York.[31,32] Prevention of AHT is extremely challenging given the complex contributing factors and our limited understanding of the triggers that increase the risk of exposure, particularly in children older than 1 year of age. Most prevention efforts focus on interventions that increase awareness of the risk of AHT associated with crying in the early period of a child's life, which may not be as applicable as the child grows older.

4.2. Differences in Case Fatality of AHT

Children 1 year old and older experienced higher case fatality than 0 year-olds. These age categories may be at higher risk of fatality due to: (1) more severe injuries through different mechanisms, (2) higher risk of extended exposure to abuse, and/or (3) higher risk of being misdiagnosed and reinjured given that they are considered at lower risk of AHT than infants.[21,33,34]

Differences in case fatality by race were not significant in this study. Because the numbers of fatal cases by age and race were so small in some instances, reliable estimates of case fatality were not obtainable. A study from the National Center for Health Statistics National Vital Statistics System found the highest rates of fatal AHT among Non-Hispanic African Americans (1.74 per 100,000 person-years) and lowest rates among Non-Hispanic Caucasians (0.55 per 100,000 person-years).[16]

While children < 1 year had the highest case fatality rates in the South, children 2 years old and older experienced significantly higher rates in the Midwest region than anywhere else. Studies have shown that Northeastern hospitals have lower rates of AHT than other regions, yet there is little evidence of an association between the hospital region and overall case fatality rate. External psychosocial risk factors and family sociodemographic characteristics can also impact the risk of mortality and may partially explain the observed differences by age and region.[35] Another possible explanation may be due to differences in documentation and accuracy of ICD-9-CM coding practices by region. Misclassification of accidental head trauma as AHT is likely to have a strong impact in the case fatality estimates given that accidental head trauma has a known high case fatality rate.[5]

4.3. Study Limitations

There are several limitations to this study. The outcomes are reliant on accurate diagnosis, documentation, and classification of a

complex traumatic injury. High sensitivity (92%) and specificity (96%) were reported with the implementation of an ICD-9-CM code-based operational case definition for AHT that involved a Child Protection Team (CPT) at a tertiary care pediatric hospital.[36] Furthermore, this study showed that AHT ICD-9-CM codes were not used in subsequent non-AHT visits of readmission in the 6 months after initial diagnosis; readmissions were related to sequelae of AHT but none of these visits were miscoded as AHT. Despite this data, it is important to be cognizant of the limitation that hospital encounters of AHT as captured in this study could involve acute hospitalizations as well as follow-up hospitalization of the same child. It is reasonable to suspect that there may be significant variability in the way in which AHT cases were coded among hospital types, healthcare providers, and a case definition based on ICD-9-CM coding only. It has been shown that children with mild injuries, younger in age, and minority children with parents not living together were at increased risk of misdiagnosis.[34] Other studies have also shown inconsistencies in the evaluation and diagnosis of AHT.[34,37–39] Wood et al. (2010) reported racial differences in AHT evaluation in reporting across 39 pediatric hospitals[38] yet Hymel et al. (2018) confirmed physician bias in only 2 out of 18 institutions.[39] Providers may have suspected AHT but did incorporate these suspicions into their diagnosis, deferring instead to law enforcement, or the medical examiner. Our identification of study participants relied on the documentation of health care providers to capture the hospitalization of children with AHT. Additionally, our study population represented all incoming cases of AHT hospitalized across the US and a selection bias necessarily occurs when we only focus on injuries severe enough to require hospitalization.

5. Conclusions

The annual incidence and case fatality rate of AHT has remained consistent throughout the study period (2000-2012). Incidence is highest among children < 1 year old, boys, non-Whites, and hospitals in the South and Midwest. Differences in incidence and case fatality rate were notable across various age groups. Children < 1 year old experienced the greatest risk of AHT, yet a significant risk of AHT was still documented in children of 2 years old and older, ages that are not often included in studies on AHT. Differences in AHT incidence in males and females remained consistent across different age groups (0, 1, 2, and 3-4 year-olds). Case fatality rate was significantly higher in the older age groups, with the lowest burden in children < 1 year old, comparable among males and females.

Our study provided new estimates for national AHT incidence and case fatality rates using the narrow definition proposed by the CDC. The greater specificity than the broad definition allowed us to show that risk of AHT remains significant in children through 4 years of age. The presentation of incidence and case fatality by age specific groups highlights the importance of increased awareness in children older than 1 year, as they retain significant incidence of AHT with higher case fatality rates. Children over the age of 1 year should not be forgotten as a potential victim of AHT in preventative and investigative efforts because the risk of misdiagnosis may be greater and the stakes for falling through the cracks are more frequently fatal.

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Appendix A. Supplementary data

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