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National, Regional, and State Abusive Head Trauma: Application of the CDC Algorithm

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WHAT'S KNOWN ON THIS SUBJECT: Abusive head trauma (AHT) is a rare phenomenon that results in devastating injuries to children. It is necessary to analyze large samples to examine changes in rates over time.

WHAT THIS STUDY ADDS: This is the first study to examine rates of AHT at the national, regional, and state level. The results provide a more detailed description of AHT trends than has been previously available.

abstract

OBJECTIVE: To examine national, regional, and state abusive head trauma (AHT) trends using child hospital discharge data by applying a new coding algorithm developed by the Centers for Disease Control and Prevention (CDC).

METHODS: Data from 4 waves of the Kids' Inpatient Database and annual discharge data from North Carolina were used to determine trends in AHT incidence among children <1 year of age between 2000 and 2009. National, regional, and state incidence rates were calculated. Poisson regression analyses were used to examine national, regional, and state AHT trends.

RESULTS: The CDC narrow and broad algorithms identified 5437 and 6317 cases, respectively, in the 4 years of KID weighted data. This yielded average annual incidences of 33.4 and 38.8 cases per 100 000 children <1 year of age. There was no statistically significant change in national rates. There were variations by region of the country, with significantly different trends in the Midwest and West. State data for North Carolina showed wide annual variation in rates, with no significant trend.

CONCLUSIONS: The new coding algorithm resulted in the highest AHT rates reported to date. At the same time, we found large but statistically insignificant annual variations in AHT rates in 1 large state. This suggests that caution should be used in interpreting AHT trends and attributing changes in rates as being caused by changes in policies, programs, or the economy. *Pediatrics* 2013;132:e1546–e1553

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KEY WORDS

abusive head trauma, abuse, children

ABBREVIATIONS

AHT—abusive head trauma
CDC—Centers for Disease Control and Prevention
CI—confidence interval
E code—external cause of injury code
ICD-9-CM—*International Classification of Diseases, Ninth Revision, Clinical Modification*
KID—Kids' Inpatient Database
TBI—traumatic brain injury

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Abusive head trauma (AHT) results in devastating injuries to the brain and is associated with retinal hemorrhages, long bone fractures, and rib fractures.[1] It was first described >40 years ago, and the epidemiology of AHT is now more clearly understood, with reported rates of approximately 15–30 per 100 000 in the first year of life.[2–6] This translates to about 1200 cases among children <1 year of age per year in the United States. Nearly one-fourth of children <2 die, and the costs to the child, family, health system, and society are enormous.[2]

A sentinel study published in 2003 reported the incidence of AHT using active prospective surveillance for the first time in the United States.[2] After that study, the first prevention program to reduce AHT rates was described in upstate New York.[7] Increasing attention has been paid to AHT prevention over the past decade, in large part because of those important studies.[8] Furthermore, Ellingson et al[3] demonstrated that hospital discharge data could be used to estimate national rates of AHT for children and yielded similar results. Because AHT is a rare phenomenon, it is necessary to include large populations of young children for multiple years to provide sufficient power to demonstrate changes in rates. Hospital discharge data provide an opportunity to carry out low cost surveillance of the incidence of AHT and to study the effects of prevention programs and policies over time.

Three recent hospital-based studies[9–11] suggest that the number of cases of AHT in young children rose dramatically in parallel with the US recession of 2007 to 2009. None of these analyses examining AHT included complete state, regional, or national population-level data. The most recent of these studies[11] included national data from most US children's hospitals and therefore may have reflected population-based trends. However, this study used a set of codes that did not discriminate between intentional and nonintentional traumatic brain injury (TBI) other than excluding those with known motor vehicle crashes. This article shows a much smaller increase in rates of nonspecific TBI than the other 2 studies, as would be expected if the recession only increased rates of AHT.[11]

In the current article, we examined trend estimates of AHT derived from 4 waves of a national probability sample of hospital discharges that is compiled every 3 years over a 9-year span to determine trends and explore regional variation. We also examined 10 consecutive years of hospital discharge data from North Carolina to assess annual state rate estimates and year-to-year variation in these estimates. We used a newly proposed coding algorithm from a Centers for Disease Control and Prevention (CDC) expert panel and applied that to *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) hospital discharge codes.[12] The results provide a more in-depth description of trends and variations in rates of AHT over time in geographically defined regions than has been available previously.

METHODS

Secondary data analyses of hospital discharge data were conducted to determine the national, regional, and state incidences of AHT. National and regional rates were calculated for the years 2000, 2003, 2006, and 2009, and yearly state rates were calculated from 2000 to 2009. The analysis included all children <1 year of age.

Data Source for National and Regional Estimates

We used the Kids' Inpatient Databases (KID) for calendar years 2000, 2003, 2006, and 2009 to calculate the national and regional rates of AHT. The KID data sets were provided by the Healthcare Cost and Utilization Project, supported by the Agency for Healthcare Research and Quality.[13] The KID contains a sample of pediatric discharges from community, nonrehabilitation hospitals.[13] In 2000, 2784 hospitals from 27 states contributed data to the KID; in 2003, 3428 hospitals from 36 states contributed; in 2006, 3739 hospitals from 38 states participated; and in 2009, 4121 hospitals from 44 states provided data to the KID.[13] The data are weighted to provide national and regional estimates. The nation is divided into 4 regions: the Northeast, Midwest, South, and West. (See Table 1 for the states in each of the regions.) The KID contains up to 15 ICD-9-CM diagnosis codes for each child admission for the years 2000, 2003, and 2006 data and up to 25 codes for 2009 data.[13] The data also contain external cause of injury codes (E codes).

Data Source for State Annual Estimates

Inpatient discharge data from fiscal years 2000 to 2009 were used to calculate yearly North Carolina AHT rates. The fiscal years for these data are from October through September. These data sets include all inpatient discharges in

TABLE 1 States in Each Region[13]

Region	States
Northeast	Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
Midwest	Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
South	Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, West Virginia
West	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

North Carolina. We obtained these discharge data from the Cecil G. Sheps Center at the University of North Carolina at Chapel Hill (North Carolina Discharge Database, Thomson Reuters, Fiscal Years 2000–2009).[14] The data include the age of the patient, information about the patient's hospital stay, payer information, and up to 24 diagnosis codes, including E codes.[15]

Coding Algorithm for AHT Cases

We used algorithms for ICD-9-CM and E codes developed by an AHT expert panel convened by the CDC to identify broad and narrow cases of definite AHT and probable AHT.[12] The broad definition is appropriate for general AHT surveillance in that it is more sensitive than the narrow definition.[12] The narrow definition is more specific in its case ascertainment.[12] Including both definitions allowed us to compare the AHT rates ascertained by each definition and their trends. This provides insight into the utility of the definitions. In most instances, for a case to be counted as AHT, there had to be at least 1 ICD-9-CM diagnosis code that indicated a TBI and an E code that classified the cause as intentional or inflicted. The diagnostic code for shaken baby syndrome (995.55) did not require an E code. Exclusion criteria included various child maltreatment codes (995.5, 995.50, 995.59) in the presence of a fall or accident code. Injuries associated with a motor vehicle crash code were excluded.

Analysis

The incidences of AHT for each of the KID data sets and the state hospital discharge files were calculated by dividing the number of AHT cases by the number of children who were <1 year of age in the same year. The coding algorithm described earlier was used to determine the numerator. Weighted counts were used for the national and regional estimates. For national and regional incidences, bridged race population estimates from the National Center for Health Statistics[16] of the number of children <1 year of age at the midpoint of the year under study were used for the denominator. Similarly, the denominator for the state-level incidence of AHT was the number of children <1 year of age in North Carolina in the fiscal year being analyzed. Confidence intervals (CIs) were calculated by using asymptotic estimates.[17]

We conducted Poisson regression analyses to determine whether there were changes in AHT rates over time. Given that the national and regional counts were weighted, we considered the sampling design when conducting the Poisson regressions. We did so by using the design effects of the sample, as has been described elsewhere.[18,19] All Poisson regressions were checked for overdispersion using χ^2 goodness-of-fit tests.

SAS 9.2 (SAS Institute, Inc, Cary, NC) was used for all data management. Incidence rates and CIs were calculated in Microsoft Excel 2007. Regression analyses were conducted in Stata version 10 (Stata Corp, College Station, TX). This study was approved by the human subjects review board at the University of North Carolina at Chapel Hill.

RESULTS

National Rates

Within the weighted sample for the 4 years of KID data, the CDC-recommended algorithm for narrowly defined AHT identified 5437 cases of AHT, for an average annual incidence of 33.4 cases per 100 000 children <1 year old. For broadly defined AHT, the CDC-recommended algorithm detected 6317 cases of AHT, for an average annual incidence of 38.8 per 100 000 children <1 year old.

Tables 2 and 3 provide annual incidences of narrow and broad AHT for the sampled years between 2000 and 2009. There was no overall trend of increasing or decreasing rates of AHT nationally for either the broad (β = 1.00, SE = 0.010, P = .72) or the narrow definitions (β = 1.00, SE = 0.009, P = .80) (Fig 1).

TABLE 2 National, Regional, and North Carolina Rates (95% CI) of AHT Cases Among Children <1 y of Age per 100 000 Children, 2000–2009, Narrow Definition

Year	National	Regional Rates			Northeast	North Carolina
		Midwest	West	South		
2000	31.2 (26.0, 36.4)	27.3 (13.7, 40.8)	38.7 (23.1, 54.2)	32.1 (23.5, 40.7)	24.0 (12.8, 35.2)	43.7 (32.3, 57.8)
2001						35.1 (25.3, 47.5)
2002						32.3 (22.9, 44.4)
2003	37.1 (31.8, 42.5)	51.8 (33.8, 69.8)	39.0 (23.6, 54.4)	34.2 (23.6, 44.8)	22.1 (13.4, 30.8)	44.3 (33.1, 58.1)
2004						28.6 (19.8, 39.9)
2005						24.5 (16.5, 35.0)
2006	31.5 (26.5, 36.5)	44.6 (28.1, 61.2)	30.9 (18.3, 43.5)	27.7 (19.1, 36.2)	23.8 (14.6, 32.9)	32.5 (23.3, 44.0)
2007						30.8 (22.1, 41.8)
2008						29.2 (20.8, 40.0)
2009	33.7 (28.9, 38.4)	43.6 (29.1, 58.2)	28.2 (18.4, 38.0)	34.2 (24.4, 43.9)	27.9 (16.1, 39.8)	42.3 (32.0, 55.0)
Total	33.4 (31.4, 35.4)	41.9 (35.9, 48.5)	33.9 (29.0, 39.4)	32.0 (28.4, 35.9)	24.5 (20.7, 28.9)	34.2 (31.0, 37.6)

TABLE 3 National, Regional, and North Carolina Rates (95% CI) of AHT Cases Among Children <1 y of Age per 100 000 Children, 2000–2009, Broad Definition

Year	National	Regional Rates			Northeast	North Carolina
		Midwest	West	South		
2000	36.9 (31.3, 42.5)	32.9 (18.1, 47.7)	45.2 (28.0, 62.4)	37.9 (28.5, 47.3)	28.9 (16.3, 41.4)	50.9 (38.5, 65.9)
2001						43.5 (32.5, 57.1)
2002						34.0 (24.3, 46.3)
2003	41.9 (35.9, 47.9)	56.3 (36.9, 75.7)	44.1 (27.4, 60.8)	39.2 (27.4, 51.0)	26.0 (15.5, 36.5)	46.9 (35.3, 61.0)
2004						31.9 (22.6, 43.8)
2005						27.8 (19.2, 38.8)
2006	36.6 (31.1, 42.1)	52.0 (33.1, 70.9)	35.3 (21.8, 48.8)	32.3 (22.6, 41.9)	28.2 (18.3, 38.1)	35.6 (26.0, 47.7)
2007						34.6 (25.3, 46.1)
2008						33.7 (24.6, 45.1)
2009	39.7 (34.2, 45.1)	50.9 (34.1, 67.7)	33.7 (22.1, 45.2)	40.1 (29.0, 51.3)	33.2 (19.2, 47.2)	47.6 (36.6, 60.9)
Total	38.8 (36.6, 41.1)	48.1 (41.4, 55.4)	39.3 (33.8, 45.3)	37.3 (33.3, 41.7)	29.1 (24.7, 34.1)	38.5 (35.1, 42.1)

Table 4 contains demographic information for the whole sample and for children who met the narrow and broad definitions of AHT. There were significantly more boys who experienced AHT, according to either the narrow or broad definition, than in the total sample ($\chi^2 = 90.3$, $P < .001$ and $\chi^2 = 84.7$, $P < .001$, respectively).

Regional Rates

For all years combined, the Northeast region had the lowest rate of all the regions at 24.5 and 29.1 cases per 100 000 children <1 year old for the narrow and broad definitions, respectively. The South region had the second lowest rates of 32.0 and 37.3 cases per 100 000 children less <1 year for the narrow and broad definitions, respectively. The Midwest reported the highest rate of AHT using both the narrow and broad definitions at 41.9 and 48.1 per 100 000 children <1 year old, respectively (Tables 2 and 3).

No regions demonstrated significant increases or decreases in AHT rates during the years under study under the broad definition. There were no significant changes in AHT rates in any single region under the narrow definition in the 4 different years of the KID database.

In a comparison of interregional trends, the comparison of the West and Midwest was the only significant finding for both broad and narrow definitions ($P = .01$; Table 5). For both definitions, the Northeast versus West and South versus West and among the broad definition only Midwest versus South were marginally significant ($0.05 < P < .10$). No other regional comparisons were significant ($P > .10$).

The regional demographic distributions of AHT cases were similar to the national distribution. Specifically, the preponderance of boys in the AHT case admissions compared with the overall admissions was found in each of the regions. See Tables 6 and 7 for regional demographic information.

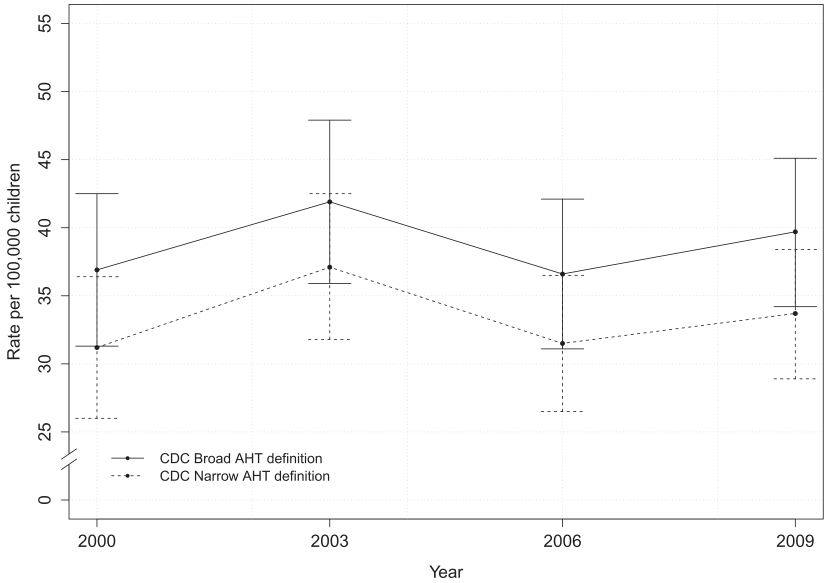

FIGURE 1
National AHT rates (95% CI) by CDC AHT definition among children <1 year of age (2000–2009).

North Carolina State Rates

During the 10 years of study in North Carolina, the CDC-recommended algorithm for narrowly defined AHT identified 442 cases, for a mean annual incidence of 34.2 AHT cases per 100 000 children <1 year old. For broadly defined AHT, the CDC-recommended algorithm detected 475 cases, for a mean annual incidence of 38.5 per 100 000 children <1 year old. No significant difference in overall linear trend was detected over the 10 years under study

TABLE 4 National Demographic Data

	Total Discharges	Male (%)	Mean Age (mo)
Total KID sample <1	6 940 140	55.0	1.0–1.2
Broad AHT <1	6283	61.2**	4.0–4.2
Narrow AHT <1	5434	61.8**	3.9–4.2

** $P < .001$.

TABLE 5 Comparing Regional AHT Trend Estimates Among Children <1 y of Age, 2000–2009; *P* Values

		Region				
		Northeast	Midwest	South	West	
Region	Northeast	—	.74	.53	.06	Broad
	Midwest	.68	—	.08	.01	
	South	.28	.11	—	.09	
	West	.05	.01	.08	—	
		Narrow				

P values based on *z*-score value with 1 *df*.

TABLE 6 Regional Demographic Information for the Narrow Definition

Region	Total Discharges	% AHT Criteria	% Total Discharges Male	% AHT Male	Mean Age[a] (mo)
Northeast	1 170 000	0.06	55.6	61.0*	3.6–4.4
Midwest	1 440 000	0.10	55.6	63.3**	3.8–4.4
South	2 730 000	0.07	55.0	60.0**	3.9–4.1
West	1 570 000	0.09	56.1	63.4**	3.8–4.4

* $P < .01$. ** $P < .001$.

[a] Because of the different sample weights for each year of the KID data, the mean age was calculated for each year, and the range of means is presented.

TABLE 7 Regional Demographic Information for the Broad Definition

Region	Total Discharges	% AHT Criteria	% Total Discharges Male	% AHT Male	Mean Age[a] (mo)
Northeast	1 170 000	0.07	55.6	59.3*	3.7–4.4
Midwest	1 440 000	0.12	55.6	61.7**	3.9–4.1
South	2 730 000	0.08	55.0	59.1**	4.0–4.2
West	1 570 000	0.10	56.1	63.3**	4.0–4.5

* $P < .04$. ** $P < .001$.

[a] Because of the different sample weights for each year of the KID data, the mean age was calculated for each year, and the range of means is presented.

for either the broad ($P = .24$) or narrow ($P = .34$) definitions.

Among all hospital discharges for all years combined, 0.03% met the narrow AHT criteria and 0.04% met the broad criteria. Boys accounted for 51.9% of all discharges but for 59.7% of all narrowly defined AHT cases ($\chi^2 = 31.09$, $P < .001$) and 60.0% of all broadly defined AHT cases ($\chi^2 = 37.20$, $P < .001$). The mean age of children in North Carolina who experienced AHT ranged from 3.0 months to 4.9 months for the narrow definition and from 3.4 months to 5.2 months for the broad definition for the 10 years analyzed.

Comparing Narrow and Broad Definitions

For the national data, the broad definition captured 14% more cases than the narrow definition ($P = .001$). However, the estimated trend by each definition was statistically equivalent ($P = .47$; Fig 1). The broad definition captured 15.9%, 14.3%, 13.6% and 12.9%, more cases than the narrow definition for the Northeast, South, West, and Midwest respectively (all regions reported $P < .05$)." However, the estimated trends for each region by each definition were statistically equivalent (all regions reported $P > .40$; Fig 2). In North Carolina, the broad definition captured 11% more cases than the narrow definition for all years combined ($P = .04$). The estimated trend by each definition was also statistically equivalent ($P = .47$; Fig 3).

DISCUSSION

This is the first study to apply the new CDC AHT algorithm to national and regional KID data and to annual state hospital discharge data. We found that the annual national incidence of AHT was 33.4 and 38.8 per 100 000 children <1 year old, depending on whether the narrow or broad definition was used. The Northeast had the lowest incidence of AHT, and the Midwest had the highest incidence. Limited regional variations in overall AHT trends were found, but only the Midwest and West had trends that were significantly different from each other. The overall North Carolina state incidence of AHT was 34.2 and 38.5 per 100 000 children <1 year old for the narrow and broad definitions, respectively.

The national incidence of AHT found in the current study was higher than most previously reported estimates.[2,3,20] This discrepancy may result from the different coding algorithm used in this study compared with 2 of the other studies.[2,3] If children who were readmitted in the same year for follow-up care due to AHT injuries are coded as having shaken baby syndrome, they would be counted more than once under the coding algorithm used in the current study. The third study by Parks et al[20] used the broad CDC coding

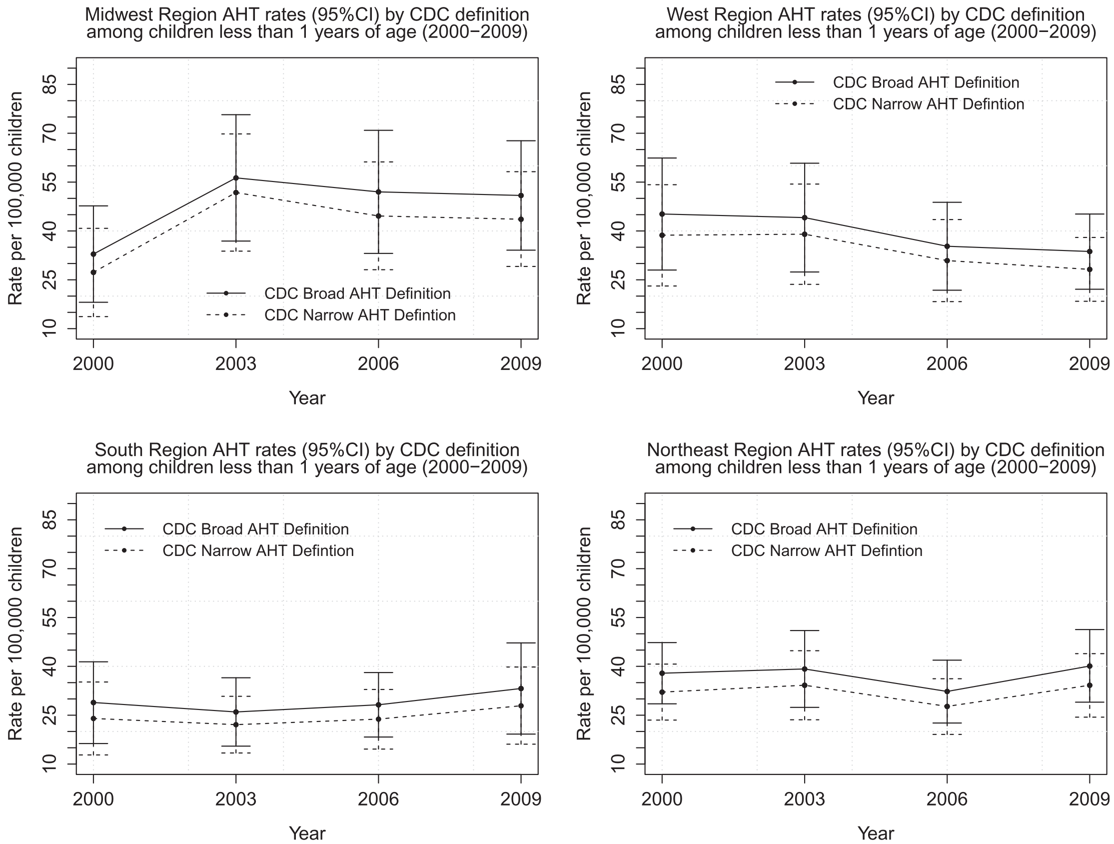

FIGURE 2
Estimated Trends for Each Region by Each Definition.

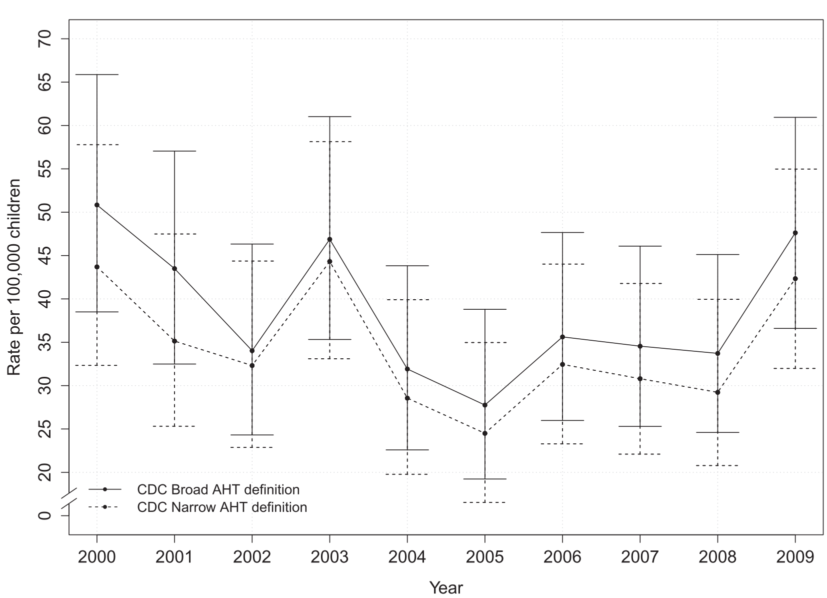

FIGURE 3
North Carolina AHT rates (95% CI) by CDC AHT definition among children <1 year of age (2000–2009).

algorithm and reported a national average annual incidence of 32.3 per 100 000 children <1 year of age. The discrepancy between this rate and the ones presented in the current study may be caused by a number of factors. First, different data sources were used. It is possible that the sample of hospitals in our study either treated more AHT cases or were more likely to use the ICD-9-CM codes in the CDC algorithm. The previous study also examined a different but overlapping time period (2003–2008) and included yearly data.[20] Although our time frame was only slightly broader (2000–2009), our study included only 4 years of data. It is possible that, had more years of data been examined, we would have found a lower rate of AHT. As in the current study, Parks et al[20] did not find significant fluctuations in national rates of AHT. One recent study did find a national AHT rate that is similar to what we found in the current study.[21] The authors applied the broad CDC algorithm to the 2000, 2003, 2006, and 2009 KID data and reported a national average annual incidence of 39.8 per 100 000 children <1 year old.[21]

It is not clear why the Northeast has lower rates or the Midwest has higher rates of AHT than other regions. It is possible that there is a greater concentration of AHT prevention programs in the Northeast. We know of 2 studies, both of which were conducted in the Northeast, that reported reductions in AHT cases ranging from 47% to 75% as a result of AHT prevention programs.[6,22] It is also possible that ICD-9-CM coding practices differ between regions, which would affect the rates found in the current analysis. Finally, there may be other external influences on AHT rates, such as the economy or unemployment, that differ between regions.

Three publications have reported an association between the recent economic recession and rates of AHT.[9–11] However, our study did not find a statistically significant increase in the rate of AHT nationally, regionally, or in North Carolina from 2007 to 2009. This discrepancy could have many causes. First, we calculated national and regional rates at 3-year intervals. It is possible that fluctuations in AHT in the years not analyzed could have demonstrated an increase or decrease in AHT rates. In North Carolina, for example, rates were higher in years when KID data were available compared with years in which it was not. Further, by using data from the Pediatric Health Information System, Wood et al[11] found that high-risk TBI peaked in 2008 and decreased considerably in 2009. It is possible that this same peak would have been found for the nation or for some regions in the current study had 2008 data been available. However, we note that a similar peak was not observed in our North Carolina data. It is also possible that pooling the data across the nation or regions muted any significant impact the recession may have had on smaller areas of the country.

There are limitations to the current study. First, although the KID data set includes a large sample of all hospital discharges, it does not include the whole universe of pediatric discharges. To account for this limitation, we used discharge weights to calculate estimates of AHT rates. Additionally, we missed AHT cases among older children by restricting our analyses to children <1 year of age. However, the incidence of AHT is much lower among children in the second year of life[2,6] than during infancy. Given that discharge data were used, it was not possible to verify that the CDC algorithm accurately identified children with AHT, resulting in likely misclassification. Additionally, because hospital discharge data were used, the sample does not include children who died of their AHT injuries before they were admitted to a hospital. Finally, we used population estimates for our denominator, not exact counts of children <1 year of age. These numbers may overestimate or underestimate the true population, which could bias the rates. However, exact counts were not available, and bridged race population estimates are the standard in epidemiologic research.

CONCLUSIONS

This is the first study to simultaneously apply the broad and narrow AHT coding algorithms to a nationally and regionally weighted data set of hospital discharges over a 10-year period and to a complete annual statewide data set over the same time period. The large and statistically insignificant year-to-year variation demonstrated in 1 large state suggests that caution should be exercised in interpreting year-to-year variation and attributing such variation to shifts in state policy or changes in the economy. Our study failed to find previously reported increases in AHT rates that have been associated with the recession. These findings highlight the need for advanced methods to better infer causality when evaluating changes in rates of AHT.

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